AL/HR-TR-1995-0203

COACH: A SAMPLE TRAINING APPLICATION FOR THE INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS)

Andrew S. Wilson
William J. Walsh

Mei Technology Corporation
8930 Fourwinds Drive, Suite 450
San Antonio, Texas 78239

Edward M. Arnold, Jr., Capt, USAF
Paul K. Daly, Capt, USAF

HUMAN RESOURCES DIRECTORATE
TECHNICAL TRAINING RESEARCH DIVISION
7909 Lindbergh Drive
Brooks AFB, Texas 78235-5352

February 1996

Interim Technical Report for the Period July 1992-August 1994

Approved for public release; distribution is unlimited.

AIR FORCE MATERIEL COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5601

ARMSTRONG LABORATORY

19961106 130

DTIC QUALITY INSPECTED 1

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

PAUL K. DALY, Capt, USAF
Project Monitor

R. BRUCE GOULD
Technical Director

JAMES B. BUSHMAN, LtCol, USAF
Chief, Technical Training Research Division

Please notify this office, AL/HRPP, 7909 Lindbergh Drive, Brooks AFB TX 78235-5352, if your address changes, or if you no longer want to receive our techinical reports. You may write or call the STINFO office at DSN 240-3853 or commercial (210) 536-3853.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1996	Interim - July 1992 - August 1994

4. TITLE AND SUBTITLE

COACH: A Sample Training Application For The Integrated Maintenance Information System (IMIS)

5. FUNDING NUMBERS

C- F33615-91-D-0651, DO 0014
PE - 62205F
PR - 1121
TA - 10
WU - 75

6. AUTHOR(S)

Andrew S. Wilson
William J. Walsh
Edward M. Arnold
Paul K. Daly

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Mei Technology Corporation
8930 Fourwinds Drive, Suite 450
San Antonio, Texas 78239

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Armstrong Laboratory
Human Resources Directorate
Technical Training Research Division
Instructional Systems Branch
7909 Lindbergh Drive

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AL/HR-TR-1995-0203

11. SUPPLEMENTARY NOTES

Armstrong Laboratory Technical Monitor: Capt Paul K. Daly; (210) 536-2981

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report summarizes activities conducted during early phases of a research project to evaluate use of the Integrated Maintenance Information System (IMIS) in aircraft maintenance training. Specifically, one IMIS component, the Portable Maintenance Aid (PMA), a job-aiding device used on the flightline, was studied to determine its potential application for training. Maintenance training embedded in the PMA can be useful if applied under the right conditions and circumstances, e.g., clearly distinguising training from the real thing, and ensuring that simulated faults neither degrade weapon system performance nor personnel safety. In a formal school environment, IMIS provides the kind of diagnostic intelligence at-the-fingertip that can enable cognitive apprenticeship training to be effective. A demonstration program called COACH, a stand-alone application that can run on a PC or the PMA, was developed to illustrate how a training application could be implemented almost immediately on the PMA. Included in the appendix are sample screens that form a model for further development of an IMIS embedded training capability. Furthermore, the report describes how any training must interface with IMIS screens to make use of the inherent maintenance knowledge contained in IMIS.

14. SUBJECT TERMS

Embedded Training, Integrated Maintenance Information System (IMIS) , Technical Training, Cognitive Apprenticeship, Instructional Design, Portable Maintenance Aid (PMA), Electronic Performance Support Systems (EPSS)

15. NUMBER OF PAGES
121

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

TABLE OF CONTENTS

Section	Page
PREFACE	v
SUMMARY	vi
LIST OF ACRONYMS	viii
I. INTRODUCTION	1
Goal	1
Background	1
The Integrated Maintenance Information System (IMIS)	4
IMIS Training Prototype: COACH	5
II. COACH	5
Rationale	6
Design	7
Dialog Boxes	8
Instructional Screens	8
User Control and Navigation	9
Screen Extension	9
Prototype Demonstration	10
The Maintenance Training Problem	10
Apprentice Level	12
Journeyman Level	13
Standard Mode	13
Explorer Mode	14
Craftsman Level	16
Performance Assessment	16
Authoring Training Scenarios	19
Instructor Options	21
COACH: Training Context	23
On-the-Job Training	23
Technical School	24
Issues of Acceptance	25
III. IMIS TRAINING	27
MAINTENANCE TRAINING MODE	27
Qualification Data	27
Training Maintenance Tasks	28
Using the IMIS Device	29
IMIS PERFORMANCE CHARACTERISTICS	30
Maintenance Training Mode	30
Accessing External CBI Systems	30
Instructional Authoring	31
Instructional Presentation	31

Task Simulations....32
Instructor Interaction....32
IMIS Training....33
Formal Training & OJT....33
MIW Training....34
PMA Training....34
AIP Training....35

IV. CONCLUSIONS....35
Appropriate Content....35
Training Approach....36
Training Environment....36
Limitations of IMIS Equipment and Software....36
Recommendations....37

REFERENCES....38

APPENDIX....40
COACH Demonstration Lessons....41
Apprentice Lessons....41
Journeyman Lessons....43
Craftsman Lessons....44

LIST OF FIGURES

Figure 1. IMIS Information Integration....4
Figure 2. Hardware Components....5
Figure 3. COACH Dialog Box....7
Figure 4. COACH Presentation Window....8
Figure 5. COACH Extension Window....9
Figure 6. Seven-Step Troubleshooting Process....13
Figure 7. Explorer Mode Screen....15
Figure 8. COACH Embedded Question....17
Figure 9. Sample Assessment Report....18
Figure 10. Journeyman Assessment Report....19

LIST OF TABLES

Table 1. Instructor/Supervisor Features....22

PREFACE

This work was conducted by *Mei Technology Corporation* on behalf of the U.S. Air Force Armstrong Laboratory, Human Resources Directorate, Brooks Air Force Base. The work was performed under Air Force, Human Systems Center contract F33615-91-D-0651/014. The original Laboratory project monitor for this work was Captain Edward M. Arnold. After his transfer, Captain Paul K. Daly assumed those responsibilities.

The authors wish to thank the following people who were involved in one way or another with the research, provided badly needed information or helped with IMIS software programs and data: Lt. Eric Carlson, Ms. Barbara Masquelier, and Dr. Don Thomas of Armstrong Laboratory, Logistics Research Division, Wright-Patterson AFB; Ms. Laurie Quill of the University of Dayton Research Institute; Mr. Rob Hohne, Mr. John Blackwell and Mr. Douglas Hand of Computer Sciences Corporation, Mr. Johnny Jernigan of NCI Information Systems, Inc.; and Major Brunsvold, Chief Ralph Wiespape, and MSgt. Larry Barker of the 149th Tactical Fighter Group, Texas Air National Guard, Kelly AFB. Furthermore, the significance placed on this project by Mr. Bob Johnson and Mr. Bert Cream cannot be emphasized enough. When the authors presented training concepts to them they were always willing listeners but reluctant to accept anything but creative approaches to IMIS training. Their persistence to get the very best, forced the research beyond the ordinary. Results to be reported later reflect their tenacious determination for innovation.

A special thanks must be extended to Capt. Arnold who exhibited patience with us during the early phases of this research whenever we seemed to be struggling with IMIS. His perseverance and dedicated focus on achieving meaningful results for the Laboratory and the Air Force eventually led us to a different approach that led to more significant results.

SUMMARY

This report summarizes activities conducted during early phases of a research project to evaluate use of the Integrated Maintenance Information System (IMIS) in aircraft maintenance training. A separate report (AL/HR-TP-1995-0014) describes the results of a Training Situation Analysis, in which the Air Force maintenance training environment was analyzed and hypotheses were developed about how IMIS could be effectively applied to maintenance training.

If one looks at the world of maintenance training as being broader than just providing technicians with the skills needed to use IMIS, two specific IMIS components have potential application. These are: 1) the Portable Maintenance Aid (PMA), a job-aiding device used by maintenance technicians while working on an aircraft, and 2) the Content Data Model (CDM) which provides access to Interactive Electronic Technical Manual (IETM) data. This report focuses on the first of these potential applications, the PMA.

Maintenance training embedded in the PMA can be useful if applied under the right conditions and circumstances. For any training embedded in an operational device care must be taken to ensure it is clearly distinguishable from the *real thing*, and safety issues must be considered to ensure that simulated faults neither degrade weapon system performance nor the safety of personnel. Prior to fielding maintenance training using the PMA, policy should be established to guide its application, and safeguards built into the software to prevent accidents or misconceptions which might arise from training data. Given these conditions, training using the PMA on the flightline could be effectively achieved. Similar restrictions do not apply to use of the PMA in a formal school. In the school environment, IMIS provides the kind of diagnostic intelligence at-the-fingertip that can enable cognitive apprenticeship training to be effective. When coupled with pedagogically sound strategies, IMIS can be used to form the foundation for a comprehensive maintenance training curriculum.

Part of this research project entailed development of a demonstration of the potential training capabilities of IMIS using the PMA. The demonstration, called COACH, is a stand-alone application which can run on a PC or the PMA. It illustrates how a training application could be implemented almost immediately on the PMA. This is not a fully operational training system, rather a specification for what PMA training might look like if it were to be developed. No attempt was made to employ advanced multimedia capabilities which would certainly enhance the presentation of computer-based training. Such capabilities are normally available on standard PCs and could significantly improve any training developed for IMIS, but currently, the PMA does not have multimedia capabilities. A detailed description of the COACH application is included in this report and screens from the model are included in the appendix. These screens form a model for further development of an IMIS embedded training capability. They describe several levels of training suitable for technicians from novice to expert; they describe how training management and administrative functions could be added to IMIS to enable it to be broadly used either in the classroom or in an OJT environment. Furthermore, the report describes how any training must interface with IMIS screens to make use of the inherent maintenance knowledge contained in IMIS.

In addition to the description of COACH, this report also briefly alludes to other types of training applications which could effectively utilize IMIS. In particular, use of the CDM to

provide procedural steps, cautions, warnings, notes, system information, and other pertinent maintenance information, offers a great potential for the development of training. More specifically, by accessing CDM data in their electronic format, training developers can directly utilize source materials in the creation of computer-based maintenance training for the PC. Such a link between IETM and courseware can take a giant leap toward achieving true concurrency in training. Further research linking IETM data with generative training systems being developed by Armstrong Laboratory, may not only permit concurrency, but also achieve a significant reduction in the manpower and effort required to produce computer-based training products. Findings from this research will be reported in the final report for this program.

LIST OF ACRONYMS

AETC - Air Education and Training Command
AFB - Air Force Base
AFM - Air Force Manual
AFSC - Air Force Specialty Code
AIP - Aircraft Interface Panel
APS - Authoring and Presentation System
ATOS - Automated Technical Order System
ATS - Advanced Training System
BIT - Built In Test
CAMS - Core Automated Maintenance System
CBT - Computer-Based Training
CEMS - Comprehensive Engine Management System
CDM - Content Data Model
DM - Diagnostics Module
DSS - Deployed Support State
EPSS - Electronic Performance Support System
FCS - Full Configuration State
FLSE - Flight Line Support Equipment
FTD - Field Training Detachment
GAIDA - Guided Approach to Instructional Design Advising
ICW - Interactive Courseware
IMIS - Integrated Maintenance Information System
IETM - Interactive Electronic Technical Manual
LRU - Line Replaceable Unit
MIW - Maintenance Information Workstation
OJT - On-the-Job-Training
PMA - Portable Maintenance Aid
RF - Radio Frequency
TO - Technical Order
XAIDA - eXperimental Advanced Instructional Design Advisor

COACH: A SAMPLE TRAINING APPLICATION FOR THE INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS)

I. INTRODUCTION

A strong demand continues for highly skilled technicians to operate and maintain sophisticated Air Force systems. Unfortunately, the Air Force and the military, in general, is subject to cutbacks in funding and resources to train technicians. In an effort to identify cost-effective training methods, Armstrong Laboratory has initiated research to explore use of electronic performance support systems technology for Air Force maintenance training.

This report summarizes initial research conducted by Armstrong Laboratory to determine the extent that the Integrated Maintenance Information System (IMIS) supports Air Force training. This report includes a review of IMIS features useful for training as well as specification of a prototype training application to run on the Portable Maintenance Aid (PMA). An earlier training needs assessment (Hicks et al., 1995) identified areas in which IMIS might provide training support. The needs assessment analyzed both technical school and flightline requirements. It alluded to the degree of support IMIS software offers various training functions, such as developing training scenarios, delivering lessons and simulations for use by trainees, maintaining trainee performance records, diagnosing student learning problems and assigning learning activities. The analysis of technical school and flightline training indicated maintenance training needs with potential applications for IMIS. This report documents the methods and results of the research leading to development of a prototype for IMIS training applications.

Goal

The value of IMIS as a job aid has been well recognized. The goal of this project was to determine whether IMIS, specifically the PMA, can function effectively as a training device in addition to its role as a job aid. This goal was approached by assessing specific maintenance training activities that best utilize capabilities of the PMA; what changes are required in maintenance training including current technical school curricular content to best exploit IMIS PMA-based training; and what changes to IMIS may be necessary to allow implementation of a training function on the PMA. Researchers studied the structure of IMIS software running on the PMA by reviewing software design documents and a prototype of IMIS to postulate its training, assessment, and course management capabilities[1]; then, developed a software prototype providing a limited demonstration of training capabilities latent within the IMIS PMA.

Background

A number of findings from the earlier research shaped design and development of the PMA-based training prototype. A key finding was that maintenance technicians require diagnostic skills training. Most maintenance activities involve following established Technical Order (TO) procedures. However, a substantial percentage of maintenance tasks[2] require problem-solving beyond TO procedures. Thus, in addition to basic TO procedures, at least some technicians need explicit training in the kinds of problem-solving skills used by expert

---

[1] See Hicks et al. (1995).

[2] Hicks et al. (1995) reported about 30% of the troubleshooting tasks investigated at Hill AFB.

troubleshooters, specifically mental-models, symptom-fault-association knowledge, procedures and strategies, and coordination processes.

A review of the training literature suggested that cognitive apprenticeship training could be an effective way to teach the complex problem-solving skills needed to achieve the level of troubleshooting expert. Cognitive apprenticeship normally involves realistic problem-solving practice, coaching, fading, and collaborative learning techniques. Data on the maintenance training process showed some aspects of apprenticeship training being used in Air Force on-the-job training (OJT), where instructors rely on demonstrations, coaching, and practice on the flightline or with dedicated training aircraft (Hicks et al., 1995). Classroom training, i.e., technical school and Field Training Detachments (FTD), relies on traditional formal methods such as lectures and written tests. However, even in classroom environments, instructors give students as much practice as possible, using maintenance simulators or actual aircraft when available. A limitation of maintenance training was that students did not receive enough practice performing maintenance tasks, especially difficult troubleshooting tasks that require problem-solving. This limitation was especially evident in the technical school environment. Since practice and repetition of maintenance activities are ways in which technicians build mental models, expand fault associations knowledge and, in general, improve as technicians, it is a critical component of maintenance training. Recently, lack of practice due to aircraft availability and course length has been remedied. Another potential way of enhancing time and facilities available is through use of the IMIS PMA as a diagnostic simulator, providing sample practice problems and guiding novices through steps necessary to determine a maintenance solution.

A review of IMIS prototype software showed a number of components with training capabilities. Chief among these are two software components: the Diagnostic Module (DM) and the Content Data Model (CDM). Principal uses of the PMA on the flightline are providing access to Interactive Electronic Technical Manual (IETM) data stored in the CDM, and troubleshooting diagnostic assistance provided by the expert DM algorithm. IMIS organizes this information for technicians through a seamless presentation of steps required to isolate a fault including TO steps, test procedures, system representations (e.g., block diagrams), and logistical data, e.g., parts available or time to test or replace, etc. These sequenced presentations can be run without the PMA being linked to an actual aircraft by providing IMIS an appropriate fault code. Since no aircraft are involved, test results must be postulated by the user.[3] Regardless of how they are provided, once given appropriate test results, the PMA can simulate the entire diagnostic procedure including verification tests, diagnostic and testing procedures, component (LRU) replacement sequences and operational checkouts.

Research suggests that problem-based learning is very effective in teaching complex skills like troubleshooting and maintenance (Gott, 1988; Collins, Brown and Newman, 1989). That is, students need to practice solving problems similar to those they will solve on the job. A principal focus of OJT is on realistic problem-solving using aircraft and simulators. However, apprenticeship-training techniques can also be applied in technical school. The PMA could serve as a focus for this model.

---

[3] In fact, if not running with a test aircraft, these results may be built into a training application so students would have access to results immediately through IMIS.

Using IMIS as a simulator meets the goals of cognitive apprenticeship. From its CDM and DM components, IMIS has the potential to model thousands of complete diagnostic scenarios covering any system for which IETM and diagnostic data are available. The DM intelligence provides a rational basis for comparison of tests and replacements selected by students with an expert. The software design challenge is embedding appropriate instruction in IMIS to relate machine and algorithmic processes to human troubleshooting strategies. If designed appropriately, a trainer based on IMIS should have the ability to provide students *synthetic experience*, compressing time required for them to develop expert performance.

The concept of *synthetic experience* is at the heart of the PMA's potential training effectiveness. Cognitive researchers believe that mental models are developed through the course of years of experience working with, repairing, and maintaining complex systems (Bresee & Greenlaw, 1992). Hence, the rise of traditional apprenticeship systems, which allow novices to gain experience in controlled, directed environments. Researchers theorize that effective computer-based training systems should provide that experience in a compressed time frame, rather than waiting for critical incidents to occur over a number of years. The researchers advocate training systems that provide exposure to a variety of faults which technicians will work with throughout their careers. They call this kind of training *synthetic experience.* We believe the PMA can provided synthetic experience by delivering short training scenarios.

A key question remains: What is the appropriate place in the maintenance training cycle to provide synthetic experience? Although a training system based on the PMA could be used on the flightline during actual maintenance activities, this is probably not desirable. Unlike actual maintenance, training focuses student attention on how to do something, i.e., process, rather than getting the component fixed! In the context of actual maintenance such use may actually distract technicians from specific problems being investigated, instead focusing their attention on the diagnostic process rather than fixing the problem. Moreover, proper application of apprenticeship methodologies require training be delivered under close supervision so that learning outcomes are placed in context, and misconceptions are not allowed to take root. Therefore, troubleshooting instructions are more appropriately provided in contexts such as technical school or formal OJT where the focus is on process rather than outcomes. However, any final determination of the relative merits of PMA-generated synthetic experience in different contexts should be based on empirical evaluation of its use.

A final concern is whether the PMA is an adequate platform for delivery of training. Because of limited presentation and interaction, the scope of simulations and use of dynamic instructional media is severely constrained. Presentation displays are restricted to line art such as that contained in the CDM IETM database. Thus, while more convenient than paper-based TOs, the PMA does not carry instruction much beyond what can already be accomplished with existing materials and creative instructional approaches. On the other hand, IETM data contained in the CDM and the intelligence represented by the Diagnostic Module do have excellent potential for training applications. However, these would probably provide more utility as core of a stand-alone multimedia training system. While the PMA may have some usefulness as a convenient platform during technical training, this is primarily as a way of introducing students to working with IMIS. A more dynamic instructional environment provided by multimedia computers should do a better job providing diagnostics training based on IMIS. There is a place for both in technical training: a multimedia training system which takes

advantage of the CDM and DM as generator of realistic synthetic experience; and, the PMA to reinforce this experience and prepare technicians for the flightline of the future.

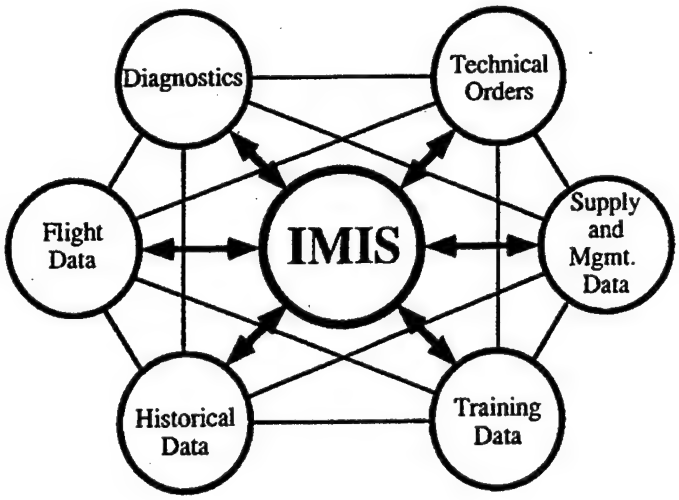

Figure 1. IMIS Information Integration.

The Integrated Maintenance Information System (IMIS)

IMIS is a computer-based information system developed to aid flightline technicians in many aspects of maintenance. It has automated capabilities expected to improve technicians' accuracy and efficiency. It acts as a maintenance management system and intelligent diagnostic aid assisting flightline maintenance technicians. The prototype IMIS, developed by Armstrong Laboratory, facilitates use of information from other computer-based information systems, such as the Comprehensive Engine Management System (CEMS), Core Automated Maintenance System (CAMS), and Automated Technical Order System (ATOS) by integrating their separate information bases in a single easy-to-use presentation format and eliminating the specialized knowledge required to operate each (see Figure 1). The heart of the system is the CDM which is a large relational database that contains information including diagnostics knowledge, technical orders, flight data, supply and management data, aircraft historical data, and training data (see Link, Von Holle, & Mason, 1987; Cooke, Maiorana, Myers & Jernigan, 1991; Thomas, 1995).

The structure of IMIS includes complex software and hardware components. The three major hardware components are: (1) the Maintenance Information Workstation (MIW), a UNIX-based desktop computer which is connected to various ground-based computer systems; (2) the PMA, a lightweight, hardened portable computer for use on the flightline; and (3) Aircraft Interface Panels which are connected to on-board computers and sensors. Figure 2 depicts the relationship among the current IMIS hardware components; the MIW, PMA, and Aircraft Interface Panel.

Because there will be few MIWs available (perhaps only one or two at each operational squadron) and because these specialized UNIX workstations are expensive and non-transportable, the current research focused on the PMA as a potential training device. While the PMA can provide access to most of the components of IMIS that seem to have training potential,

its small screen, poor presentation quality, and limited keyboard severely restrict the kinds of training interactions that could be implemented.

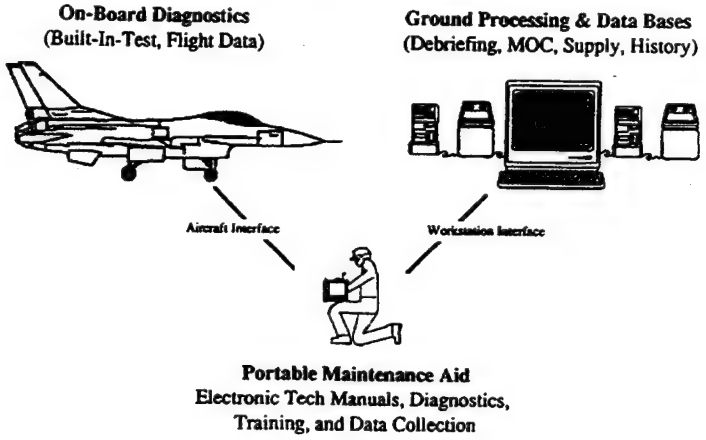

Figure 2. Hardware Components.

IMIS Training Prototype: COACH

On the basis of conclusions drawn from earlier phases of this research, a prototype application was developed demonstrating application of key training components of IMIS. This prototype contains sample lessons aimed at Apprentice, Journeyman and Craftsman levels for F-16 maintenance technicians. Lessons show how information from the CDM might be applied to training within constrains of IMIS' Authoring and Presentation System (APS)[4]. The application also models techniques which could be used to apply troubleshooting intelligence of the DM to instruction and performance assessment. The COACH prototype application is described later in this report.

II. COACH

An independent demonstration prototype of a PMA-based training application was developed. The prototype emulates many functions of the PMA that can be integrated into training; and the sample training scenario demonstrates how addition of generic instructional messages to IMIS' database could be used to generate troubleshooting training for a variety of different aircraft subsystems. The IMIS training prototype called Computerized On-line Advising and Contextual Help, or COACH, incorporates a cognitive apprenticeship methodology in its instructional approach. Cognitive apprenticeship training fits the levels of the IMIS troubleshooting prototype very well.

COACH was developed as a stand alone application to allow for flexible, practical and easy demonstrations using either a PC or the PMA. The prototype COACH concentrates on teaching technicians problem-solving skills needed for troubleshooting. It focuses on complex troubleshooting rather than maintenance procedures because 1) IMIS already provides procedural job-aiding to technicians, so once a technician masters using the PMA, procedural tasks should

[4] The APS is software in which IMIS applications are authored. Most, if not all, of the COACH application prototyped here should be reproducible with the APS.

be relatively easy; and 2) troubleshooting is, perhaps, the most difficult aspect of maintenance to learn, so COACH concentrates on building and reinforcing troubleshooting skills. Furthermore, access to the intelligence and knowledge in IMIS's DM and CDM provides potential for increasing effectiveness in troubleshooting and problem solving that traditional training does not afford.

Limitations of the APS and PMA present some fairly serious restrictions on the kinds of instructional approaches that can be used to develop and deliver training. COACH was developed with these limitations in mind.[5] In its current form, COACH demonstrates training that can be developed *reasonably, now,* with minimal change to presentation media or interaction capabilities of the APS or PMA. Despite the fact that COACH was designed around capabilities of the PMA,[6] the prototype was built using screen images taken from the MIW version of IMIS rather than making a seamless interface with IMIS' databases. Presentation screens were "grabbed" directly from the IMIS MIW to streamline the prototyping process. Diagnostic and presentation functions of the PMA and MIW are equivalent throughout troubleshooting activities, however, MIW screens have a graphical look, featuring three-dimensional buttons and scroll bars, and halftone shading. It is certainly possible that PMA displays may eventually have similar or better graphic qualities. Indeed, the PMA display is capable of presenting screens that use up to sixteen shades of gray, or of displaying MIW screens used for the COACH prototype.

Rationale

Cognitive apprenticeship is distinguished by the creation of a mentor relationship between student and teacher. This mentor relationship provides direction through guidance, motivation, and positive reinforcement. The *mentor,* i.e., COACH, works closely with the student to explain concepts clearly and provide new challenges while gradually weaning an apprentice from reliance on its expert advice. This concept of *fading* has been built into COACH. While running apprentice scenarios, equipment test selections are made by the IMIS DM, as usual and explained to the novice by COACH. At the Journeyman level, a student suggests tests or replacements to COACH, and is either encouraged or corrected by the *mentor.* Finally, at the craftsman level the trainee makes all decisions independently, then receives expert critique from COACH.

The concept behind COACH training is to reuse generic instructional strategies whenever possible based on context of the transaction, and to add content-specific instruction to the CDM, attached to particular components of the IETM database. As such, COACH lessons will have a consistent feel from one to the next. In fact, when moving from one diagnostic training scenario to the next, actual instruction and advice offered by COACH will differ very little. Breadth of instruction is accomplished by using thousands of potential diagnostic scenarios that can be generated by IMIS based on the fault codes input and the various subsystems or sets of plausibly faulty components implicated by each. Therefore, although COACH instructional messages remain generic, they are given specific context in relation to the current diagnostic scenario or IETM being explored. This minimizes programming required to implement COACH by limiting

[5] This is not to say that elements of IMIS could not provide an excellent basis for computer-based training, or that the PMA, if it were enhanced with the ability to present audio, video and enhanced graphics, could not be used as a superb training device.

[6] In fact, COACH has been tested and runs on the PMA.

content-specific instructional messages and interventions to be authored. Yet, relatively few standardized instructional messages form the basis for a large number of possible scenarios, each focusing on different subsystems, faults and possible tests. Taken together, these should aid students in developing mental models and help technicians in gaining *synthetic experience* on realistic troubleshooting tasks with common or unusual faults.

Design

To implement training on the PMA using the cognitive apprenticeship metaphor, IMIS' intelligence was personified in the form of a veteran technician, i.e., *coach*. Because COACH builds training around actual IMIS diagnostic scenarios, it is important to have a look distinguishable from routine IMIS interactions. Using this figure provides a familiar, easily recognizable motif for IMIS training interactions. COACH prototype screen displays appear in the appendix. The appendix shows standard IMIS screens and COACH dialog boxes or other features superimposed. A working prototype is available for viewing, however, by following screens in the Appendix the reader can get an accurate portrait of IMIS instruction, and the look and feel of the PMA training interface.

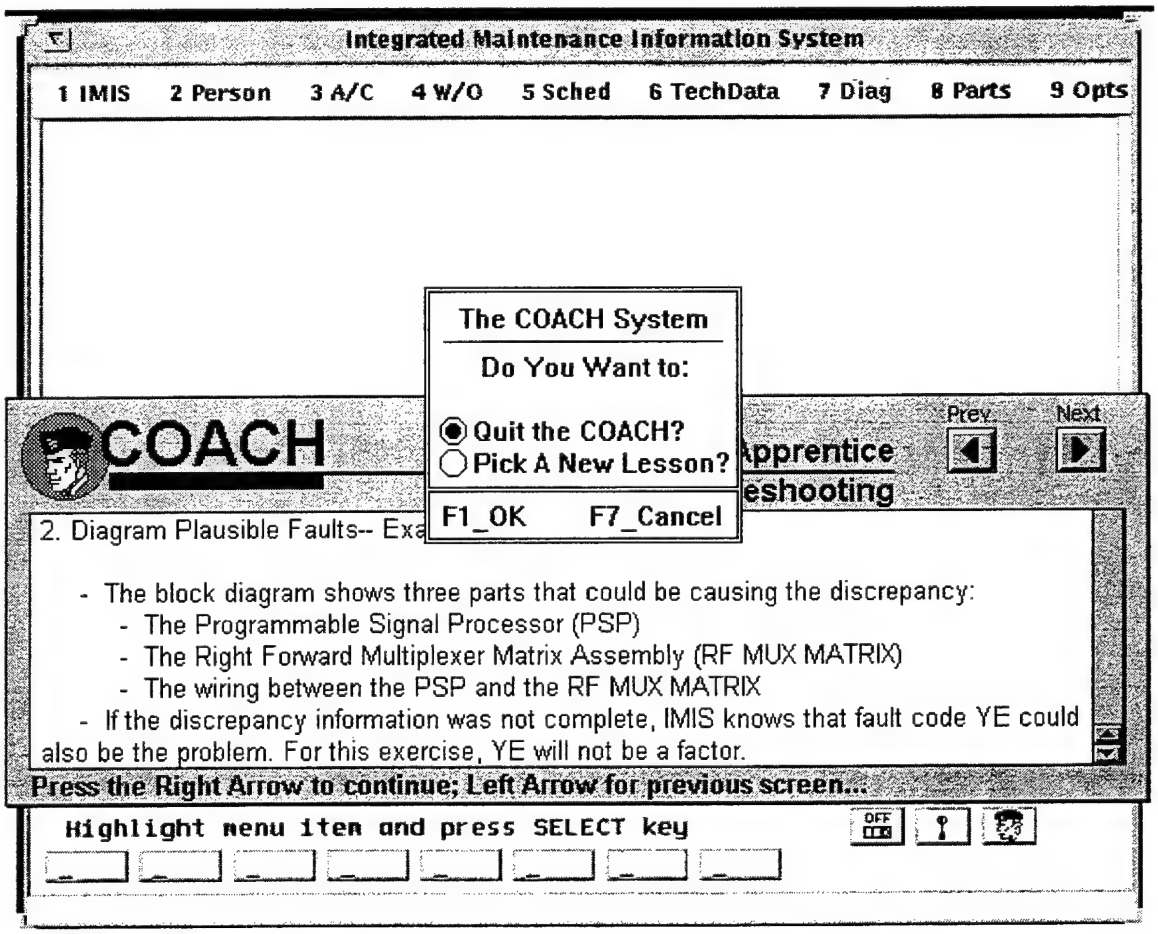

Figure 3. COACH Dialog Box.

Dialog Boxes

COACH dialog boxes feature a unique interface making them easily distinguishable from regular IMIS dialog boxes. This interface consists of a double line construction and the simple title, "*The COACH System*" running across the top (see Figure 3). COACH training screens are also easily identifiable by the iconic image of the *coach* appearing on the screen border. Functionally, COACH dialog boxes work just like any IMIS dialog box. They employ the IMIS convention of titled *radio buttons*[7] for user selection, then a choice of function keys[8] to complete the interaction. Dialog boxes in COACH can be navigated just like IMIS either by keyboard, e.g., TAB and Arrow keys, or by mouse. These COACH navigation artifacts are all within APS capabilities without modification. COACH dialog boxes have three discrete areas: a title, a selection area, and an action area.

Instructional Screens

COACH instruction appears in easily identifiable windows overlaying IMIS displays (see Figure 4). The window looks similar to IMIS screens, except for a wide gray border, a graphic of *coach* in the upper left hand corner, next to "**COACH**" in bold type. The presentation window is slightly wider than the IMIS screen so that it always appears to be *floating* in front (see Figure 5). These COACH design standards will allow screens to be built using current IMIS software tools, while keeping training scenarios easily distinguishable from standard IMIS TO procedures.

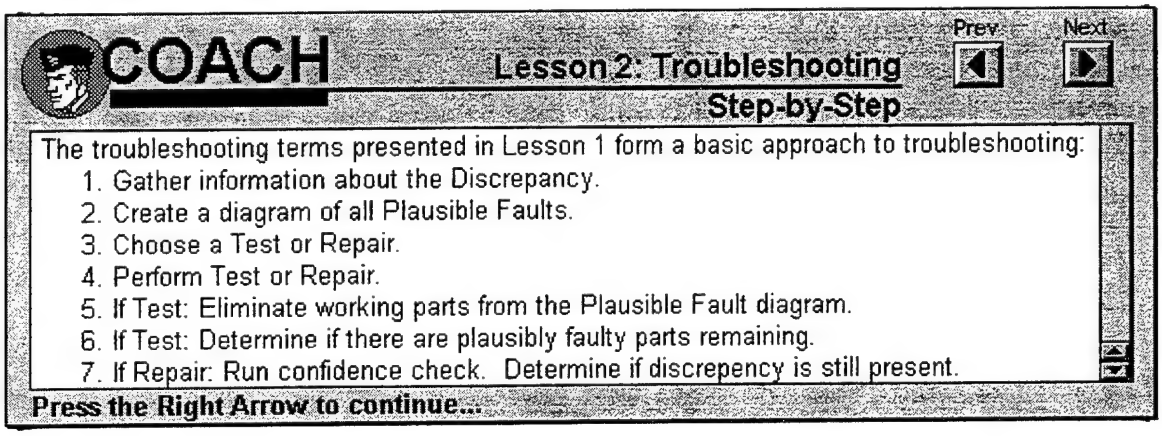

Figure 4. COACH Presentation Window.

Like the dialog boxes, the COACH presentation window is horizontally divided into three portions. The top contains the COACH icon and title of the window, e.g., name of the current lesson or diagnostic level. In the upper right corner are basic navigational tools—the right and left arrow buttons—which permit the user to move forward through instruction or back to review. Like IMIS these buttons can be activated from the keyboard or with the mouse. The center portion of the window is for information presentation. This space is white following IMIS convention. A scroll bar can be activated to allow presentation of longer text passages. In

---

[7] These are small circles that enclose a dot when selected (as shown in Figure 3).

[8] COACH mimics IMIS use of function keys to navigate. The IMIS specification and prototype have function keys implemented in both hard form, e.g., buttons, and soft form, e.g., screen buttons which can be pressed with a pointing device.

general, text on individual screens should be kept short and to the point. The bottom gray margin of the COACH window is for user guidance, e.g., this line tells the user what to do next.

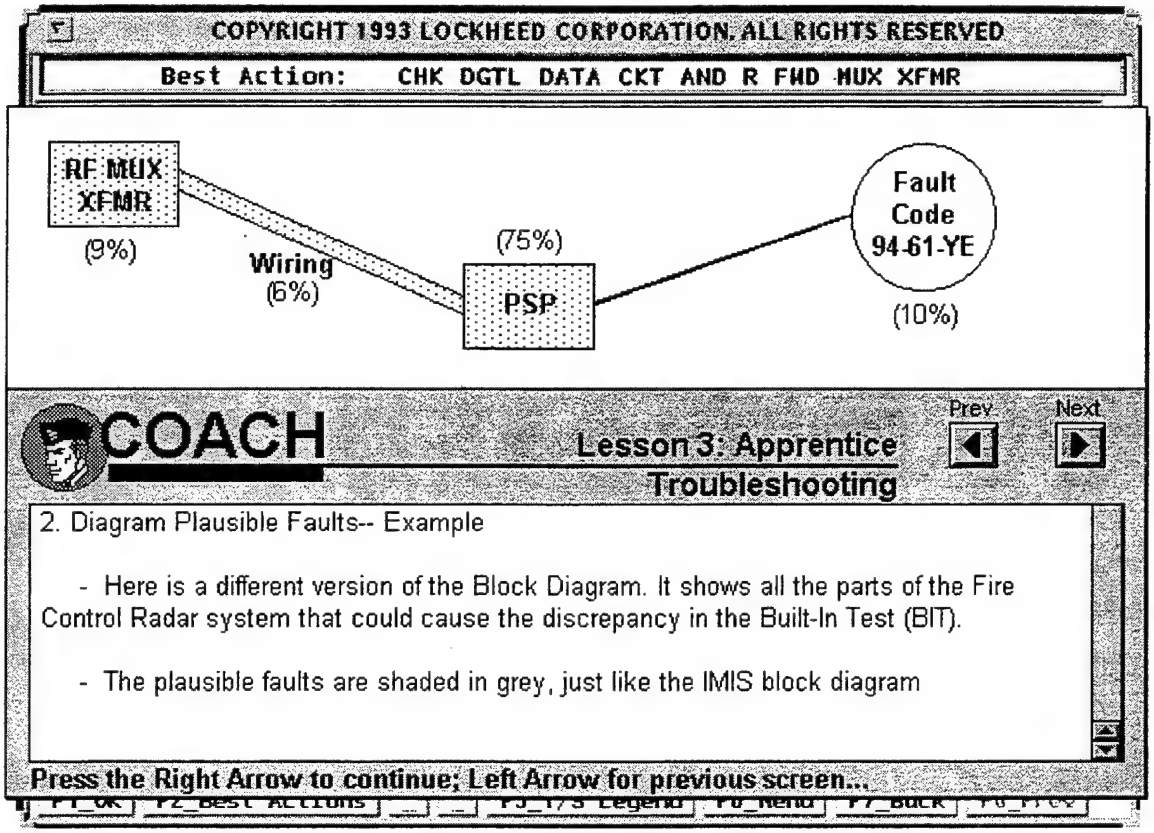

Figure 5. COACH Extension Window.

User Control and Navigation

All control and navigation in COACH is performed with the PMA *Help* key, and the F7 key keeping it as close to IMIS as possible. The *Help* key on the PMA keyboard[9] permits the user to hide or display the COACH window. In this way, the user can view the IMIS screen underneath COACH, then retrieve the COACH instructional screen. The F7 key allows the user to cancel the current COACH task or quit COACH entirely to run IMIS in normal mode.[10] Finally, the F2 key presents help about COACH and available function keys. We recommend insertion of a COACH icon on IMIS screen to make training readily accessible (see Figure 3). Finally, clicking on the coach icon in the COACH presentation window, results in information "About COACH."[11]

Screen Extension

When COACH presents instructional graphics such as a flowchart or system model, it extends the standard COACH window to do so. A plain white field with a border is attached

---

[9] F9 on a standard PC.

[10] This approach follows the IMIS standard of F7 to cancel a task.

[11] This message can also be seen by pressing the F2 function key.

above the COACH window, effectively doubling the window's size (see Figure 5). This field takes on all characteristics of a typical COACH. The extension window also shows results of student performance or assessment report information.

Placement of the COACH window was conceived to make use of as much PMA screen area as possible, while allowing users to see function keys across the bottom of the IMIS screen. COACH was designed so that the window would never cover up the title of the IMIS task in progress. Although COACH occasionally covers IMIS screens, the user can temporarily hide the COACH display.[12] Additionally, COACH hides its window whenever users must interact with IMIS. COACH screens automatically reappear whenever predetermined training conditions are met such as the need to explain the next required step or recommend an action to the user. When COACH is implemented as part of IMIS, more user control such as size and position of the COACH window may be desirable.[13]

Prototype Demonstration

The COACH prototype running on a 386 laptop computer was demonstrated and evaluated at Luke AFB during the week of November 15-19, 1993 by a maintenance trainer and apprentice technician.[14] Participants were asked about the structure of COACH, feasibility of using it for training, and what effect it may have on maintenance training. The maintenance technicians were also questioned to determine whether they retained information presented by COACH. The purpose of this formative evaluation was to obtain feedback about COACH to make minor adjustments in its approach. The novice technician and journeyman trainer were both excited about COACH's training potential. After finishing three sample lessons at the *Apprentice* level, the novice technician wrote, "I think I learned more today about half-splits than I have in three months here [on the flightline]!" The journeyman, a 5-level technician with nine years in the maintenance career field and more than four years as a maintenance supervisor wrote, "[COACH] is very easy to use, and should help a trainee... I believe anything that will teach how to troubleshoot will help."

COACH was also demonstrated at the *15th Interservice/Industry Training Systems and Education Conference* in Orlando, Florida on November 29th, 1993. Developers demonstrated the interaction between the PMA, COACH and users for one diagnostic scenario in each mode available, i.e., apprentice and journeyman levels. Considerable interest was exhibited by attendees regarding re-purposing job aids for training and the concept of non-diagnostic intelligent tutoring, (see Gugerty, 1994).

The Maintenance Training Problem

Training troubleshooting skills in technical school and OJT is likely to be important to the Air Force for several years. There are pressures to downsize active forces, reduce overall maintenance costs, and reduce diagnostic errors. Elimination of Field Training Detachments will

---

[12] By pressing the *Help* key users can toggle the display on and off without losing any information or interrupting the current lesson.

[13] We are uncertain whether or not the APS can create moveable or resizeable windows, however, such characteristics are standard features of most UNIX-based user interfaces.

[14] Although a larger sample (n=2) would have been preferable, more technicians were not available, since most were part of the experimental pool for a critical evaluation of IMIS taking place at the same time.

impact the timeliness and quality of maintenance training. This will be particularly true of practical troubleshooting exercises for novice technicians and development of the coordination knowledge necessary for experts. One solution might be to stress troubleshooting skills and provide more practice during technical school,[15] however, the issue is not so easily solved, since complex concepts and strategies involved in troubleshooting are not easily taught until novice technicians have gained a measure of flightline experience. Conversely, troubleshooting training may be effectively delivered to journeyman technicians (three-and five-level) on the flightline, but that would require an expansion of OJT resources, the use of flightline equipment and time away from the job. In fact, as pointed out, this responsibility was handled by the FTDs, but they are being eliminated.

A training system like COACH, based on a functionally efficient job aid like IMIS could address several of these problems. First, during technical school, IMIS could be used to structure a novice technician's early experience regarding the demands of flightline diagnostics without the need for expensive operational equipment or costly simulators. Running on the PMA or a stand-alone PC, COACH could guide an apprentice through scenarios until the student achieves the desired level of proficiency and is certified.[16] This is quite possible since IMIS already has the ability to structure work orders for individual technicians and gather performance data; COACH could utilize these capabilities to provide cognitive apprenticeship training. Second, IMIS could be used in technical school to provide guided practice. This would ensure that technicians effectively utilize additional technical training time and resources. COACH could be used on the flightline by the supervisor of a newly graduated technician to guide the apprentice through tasks or procedures the supervisor knows will be needed soon. This *just-in-time* approach allows the supervisor to maintain control over a technician's training, frees the supervisor from having to personally supervise each trainee all the time, and provides both supervisor and trainee with feedback from IMIS about the technician's progress. A technician's performance could be compared to some pre-established norm or to other technicians performing the same job or duties. Supervisors and technicians could see how they are progressing according to schedule, tasks selected to master, rate of performance, accuracy, and any number of other variable which are automatically collected by IMIS. Finally, COACH could provide training to technicians in the ready room. Ready room training might take the form of technicians manipulating IMIS procedures on the PMA with COACH intervening at strategic times to point out why certain steps are being taken, or posing questions to the technician about what the next step should be. Such a training environment could be extended to allow technicians to work with COACH after duty hours in the base education center or running on the technician's own PC.

As described, the bulk of COACH instruction revolves around generic troubleshooting training interwoven with actual IMIS diagnostic scenarios. COACH instruction is integrated with IMIS diagnostics such that technicians practice solving simulated troubleshooting problems

---

[15] In fact, most maintenance technical training has been lengthened to provide more practice time on actual aircraft.

[16] MAJCOMs could indicate the level of proficiency and the specific maintenance tasks or procedures required before a student could be certified competent to graduate. IMIS could structure these items in its database, collect individual student performance data, and indicate deviations from normal learning rates for instructors. COACH along with the instructor would provide a structured learning environment by demonstrating and discussing what a student needs to accomplish next.

while being guided by IMIS' diagnostic module. By using a variety of different fault scenarios, COACH creates synthetic experience for students. Through repeated exposure to drill and practice, test and repair procedures are internalized and technicians construct mental model knowledge. Because COACH's training is provided in the context of IMIS's diagnostic expertise, and COACH explains troubleshooting strategies being used by the DM and relates them to human troubleshooting techniques, COACH lessons reinforce troubleshooting skills and coordination strategies.

COACH training provides three achievement levels reflecting typical levels of maintenance technicians--apprentice, journeyman and craftsman. Apprentice training relies entirely on the DM for guidance. At the journeyman level, students are more actively involved, demonstrating their knowledge by selecting tests, and predicting results. The DM provides immediate feedback regarding the efficacy of student choices. Finally, at the craftsman level, the DM does not provide recommendations or feedback. Rather, after completing the diagnostic scenario, students receive reports comparing their performance to the DM's best path.

Apprentice Level

Apprentice level training provides an introduction to COACH and three exemplar lessons that familiarize students with a generic, seven-step troubleshooting procedure. The introduction and two of the lessons have a fixed-content. Each may be repeated as often as required, but the information and presentation in these lessons does not change. The third lesson runs through a typical IMIS diagnostic session, with COACH intervention at specific points. The lesson serves as a template for other similar IMIS diagnostic sessions.

In general, the introduction explains controls available to students while working in COACH. The introductory lesson welcomes the student, introduces COACH, and explains basic navigation procedures such as choosing instructional levels,[17] picking a lesson and hiding or quitting COACH.

The first lesson introduces students to general troubleshooting strategies. The lesson defines specialized terminology used in troubleshooting including *discrepancy*, *plausible fault*, *hypothesis*, and *elimination*. It also introduces students to a simple troubleshooting procedure. The objective of the lesson is for students to recognize terms used by IMIS and become familiar with the troubleshooting process.

Lesson two walks students through the seven-step troubleshooting procedure (see Figure 6). At each step of the procedure, conditions are explained that indicate when students should proceed to the next step or return to a previous troubleshooting step. The lesson uses an automobile ignition system as an example to ensure that students focus on troubleshooting procedures rather than specifics of a system.[18] After completing this lesson, students know the sequence of the diagnostic process and how each step relates to the next.

---

[17] Navigational control throughout COACH has been left up to the student's discretion, i.e., the student can select the level of difficulty. However, once a level is selected, the student is locked in to that level until the lesson is completed or aborted and restarted in another level. For implementation, changes to student control options can easily be changed by an instructor or supervisor.

[18] The example was selected because of the familiarity of the parts, e.g., battery, fuel tank, fuel pump, carburetor, spark plugs, coil etc., however, when implemented, another familiar system could be used.

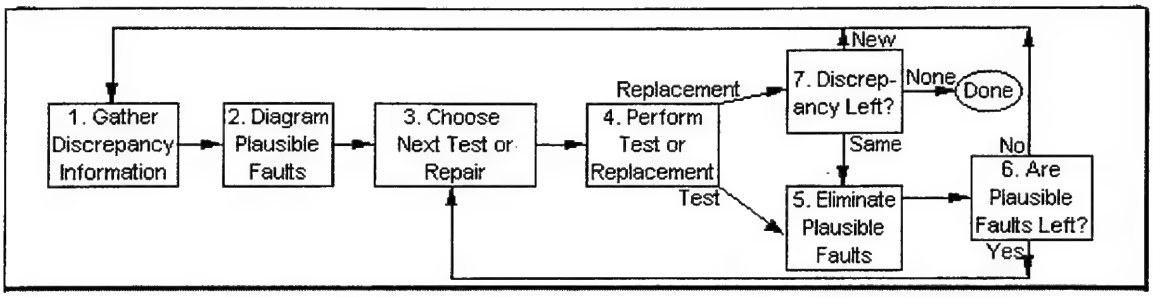

Figure 6. Seven-Step Troubleshooting Process.

The third lesson is a guided tour through a simulated IMIS diagnostic session. In this simulation, IMIS makes all decisions and COACH explains each choice made. The approach allows students to practice troubleshooting strategies while becoming familiar with IMIS. At the apprentice level, the student is relatively passive, i.e., receiving instruction and watching what happens next. Whenever IMIS makes a choice of a troubleshooting test, COACH explains what was done and why. Currently, the COACH prototype operates with a single fault isolation procedure, however, when implemented, these generic instructional messages can be integrated with any fault code or subsystem. If implemented in technical school, COACH's lesson format would be repeated several times with a different fault code and *faulty part* designated each time for IMIS to diagnose for students. In this way, this simply structured lesson can generate numerous synthetic experiences for students. The objective of the lesson is for students to understand what IMIS is recommending and why recommended tests or replacements eliminate plausibly faulty parts to isolate the problem. Students will encounter many supporting objectives along the way such as identifying component failure rates, why one test is selected rather than another, the effect of replacing a part, etc.

Journeyman Level

Journeyman level is comprised of two instructional modes: Standard mode and Explorer mode. Each has its own unique features as are described below.

Standard Mode

Standard mode is a learner-directed simulated diagnostic session. The learner or instructor provides-a fault code which automatically triggers IMIS to assemble appropriate TOs, build a *plausibly faulty* set, and determine appropriate tests and replacements. The actual *faulty part* for the scenario could be instructor or supervisor selected, or randomly generated by IMIS based on a student's needs. At each decision making point, e.g., "choose next test or repair," IMIS would present the information it uses to make a recommendation short of actually recommending a particular action or rank ordering tests according to the best action. IMIS will provide the expert information from which it draws its conclusions, but COACH will require students to determine which test or replacement to perform. The journeyman-student must select the action believed to be the best choice. COACH's on-line advisor provides hints on demand, and will explain the rationale for procedures and strategies. COACH will also remind students to consider certain factors, such as failure probabilities and time to test or replace components, before allowing students to choose the next action. Following completion of a scenario, students' actions are compared to those IMIS would have taken. A report is also provided showing student efficiency in terms of time required to solve the problem, number of tests and

replacements conducted, and the efficiency of the student's elimination strategies (half-split, working backwards from failure point, etc.). In this standard mode students are using metacognitive processes to solve realistic problems in highly realistic environments. Such training leads to higher transfer of learning and better retention (Collins, Brown and Newman, 1989, Gott, 1988).

Explorer Mode

In explorer mode, at its simplest level, COACH operates without using the DM. Rather than providing instruction and advice in context of an IMIS diagnostic scenario, COACH simply provides the interface for exploration of CDM database elements. Explorer mode provides a means for technicians to develop working mental models of complex systems. Technicians can explore and study TOs, system schematics, component failure probabilities and other information experts use to create mental models such as symptom-fault associations, strategies, procedures, and coordination processes. Depending on the level of graphic information stored in the CDM, explorer mode could include instruction that compares TOs and schematics to exploded technical illustrations of actual components and subsystems.[19] Explorer mode is based on IMIS work cards and on TO options found on IMIS *TechData* menu. *Work cards* are mini presentations of various TOs. These options provide users direct access to data stored in the CDM. They include high quality graphic views of components, explanations of the purpose and location of components, and links to presentations of related components and systems. Using IMIS work cards or TO options, users can look up procedures or see components of a subsystem such as the ejection seat or multi-function display. Users can electronically "thumb through" repair or diagnostic procedures and view tasks involved. To enhance this IMIS capability and make it effective for teaching mental models, COACH provides access to the data while enhancing them with graphics depicting models of the system. COACH should also provide access to DM data not normally displayed such as failure probabilities, associated plausibly faulty components, and parts spanned by possible tests. COACH also poses questions at appropriate intervals to test learners' knowledge of systems and components. Figure 7 shows what an explorer mode screen designed around a work card display might look like. TOs and work cards specified as part of IMIS can be made to function in COACH explorer mode with little modification. Some program modifications may be necessary to provide more connections among various components and to enable real-time generation of enhanced mental models created from CDM data such as pictures, parts spanned by tests, plausibly faulty sets, and failure probabilities.

In technical school classrooms COACH could be used by an instructor as a valuable tool for displaying information about aircraft subsystems, or to lead into discussions of the function and interrelationship of various components. It can also provide students important synthetic experience working with TOs or performing test, replacement and operational checkout procedures. COACH has the potential to create synthetic experience even before apprentice technicians have had the opportunity to work with actual aircraft. In explorer mode, COACH can be programmed to direct students through procedures using flatboard simulators such as the combined flatboard and cockpit simulator that was formerly used in avionics training at Lowry AFB. While even flatboard simulators are expensive, and limited to few students working with

---

[19] The COACH prototype only demonstrates standard mode since portions of IMIS that explorer mode is conceptually based on were not fully functional in the early IMIS prototype.

them at one time, in an instructor led scenario, an IMIS diagnostic simulation could deliver training to a number of students simultaneously. Or alternatively, each student could work independently using IMIS, with the instructor available to answer questions and direct learning activities. This approach also has advantages for instructors since they can utilize training time more effectively to assist students on exactly those skills or knowledge elements they appear to be having most trouble with. The time savings should enable students to complete more practice exercises and increase knowledge of aircraft subsystems. Throughout the learning process students will be gaining additional experience using IMIS which will eventually be their principal source of TO information and diagnostic advice. Finally, students will learn valuable strategies to use when confronted by a fault not solved by following TO procedures.

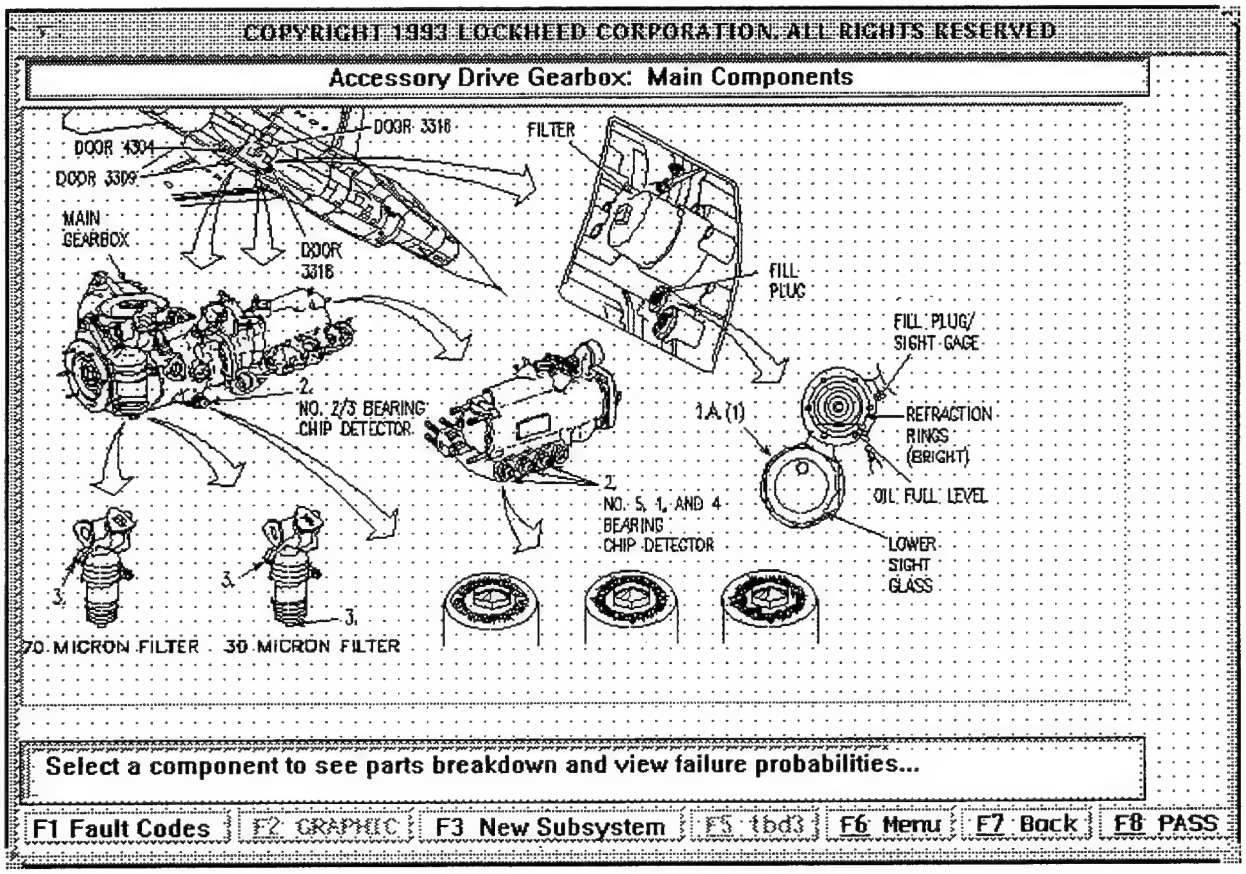

Figure 7. Explorer Mode Screen.

Craftsman Level

At the Craftsman Level, COACH again provides two modes: Craftsman mode and Instructor mode. Craftsman level is primarily intended for use by instructors for classroom demonstrations and as drill and practice for advanced students.

In Craftsman mode, COACH provides no assistance. IMIS still provides part failure probabilities and other information normally available from schematics and TOs to facilitate diagnostic decision making. Following completion of a scenario, actions taken by users are compared against IMIS recommendations and a report is generated showing student efficiency in

terms of time required to solve the problem, number of tests and replacements conducted, and elimination strategies (half-split, working backwards from failure point, etc.).

Normally, access to instructor mode should require a password. In this mode, instructors will be able to configure IMIS with fault codes and faulty parts to generate *training* work orders for individual students or a class. Then, when students log on to IMIS, they will encounter a *training* work order. The *training* work order automatically invokes COACH at a proper level for the student and directs the student to perform the work order just as IMIS normally does. Results of the simulation exercise can be used by the instructor or supervisor for student assessment or remediation. Instructor mode also allows instructors to provide fault codes and faulty parts for interactive classroom demonstrations. In such a demonstration COACH could be used to explain the rationale behind IMIS's actions or the instructor can use COACH to pose questions about actions students would choose in a procedure.[20]

Performance Assessment

Assessment features in the COACH prototype are modest compared to the elaborate assessment reports that could be developed using IMIS' capabilities. The goal of the prototype was to highlight points where assessment could be provided and create an assessment framework. Assessment reports should be provided at each COACH training level. For the apprentice level, assessment should be provided following completion of each lesson. A variety of reports could be provided including actions taken and time elapsed. For students working through journeyman or craftsman scenarios assessment reports should be similar to apprentice level while tracking other important variables. Prior to implementing COACH, users should be surveyed to determine the kinds of information and reports that would be useful to supervisors, instructors and students.

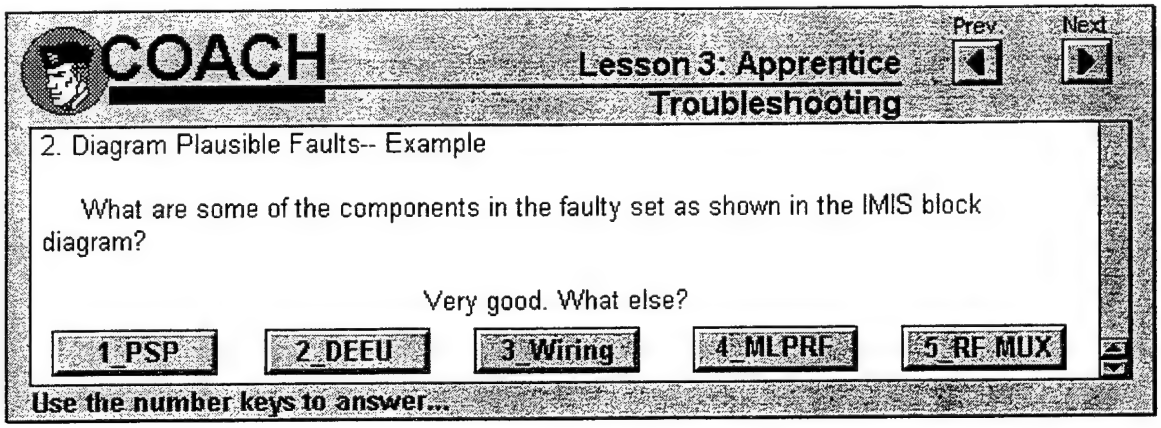

Figure 8. COACH Embedded Question.

COACH uses several types of embedded questions (see Figure 8). This example demonstrates how students select plausibly faulty components. Using a simplified model, other types of questions require students to use the *TAB* and *F1* keys to select components that could be eliminated if a maintenance test was passed. The kinds of interactive assessment that can be

20 In the COACH prototype, instructor mode controls have not been implemented because only one diagnostic scenario is available.

built into COACH lessons are practically unlimited. COACH might include questions which require students to match troubleshooting terms with their definitions, or identify points to be tested for half-split. Simple reports including number of questions attempted versus percent correct should be sufficient to provide students, instructors, and supervisors performance feedback. An option may also be to list questions missed with correct answers for student review.

COACH post instruction assessment reports are relatively simple. Assessment is based on the number of questions attempted versus number correct. Apprentice lessons are concerned with building the students' grasp of data used to make troubleshooting decisions and building mental models, therefore, assessment embedded in the lesson includes selecting components in the plausibly faulty set, selecting subsystems that contain implicated components, or specifying parts spanned by a test. Embedded questions appear throughout the instruction as well, but these are not part of formal assessment since they are designed to direct students learning rather than to evaluate their knowledge or performance. Feedback to questions is immediate. When a question is missed COACH tells students the correct answer, or informs students when the answer is correct. (see Figure 9).

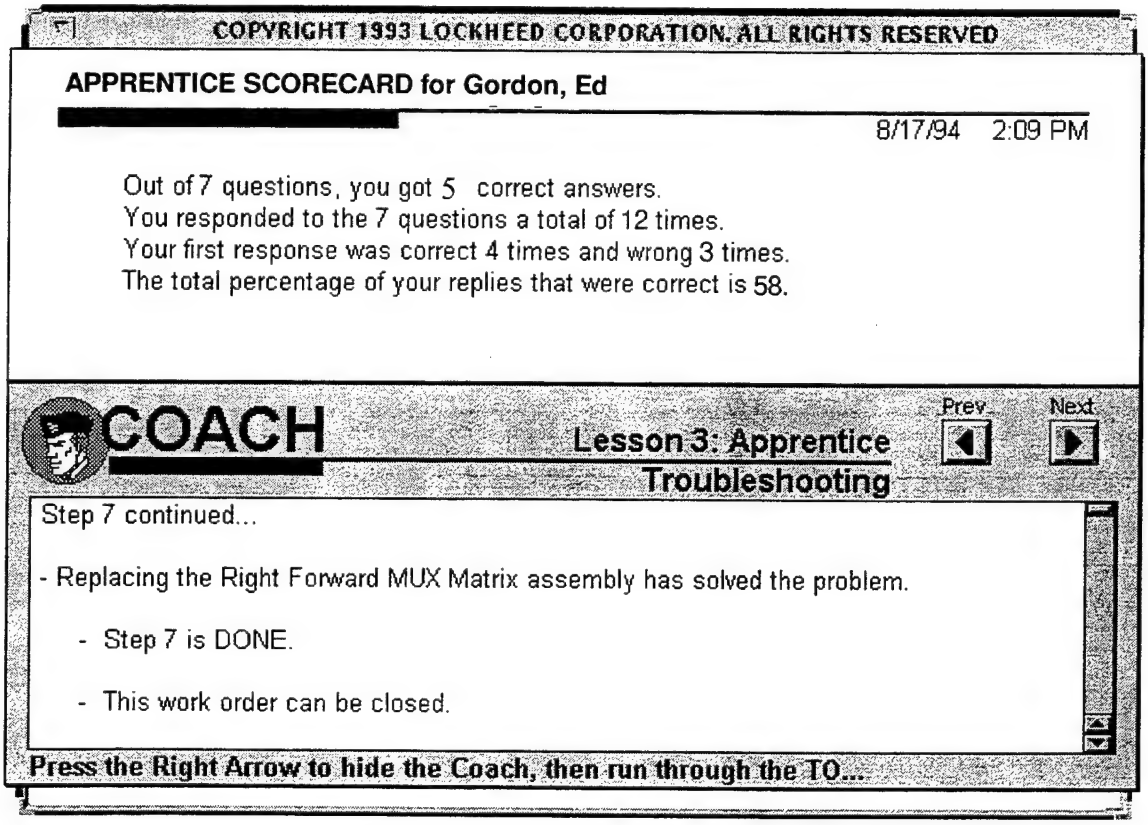

Figure 9. Sample Assessment Report.

Note: Several kinds of assessment questions may be used, some requiring the student to respond several times. The assessment report displayed above may need to be tailored to fit user needs and take advantage of potential IMIS capabilities.

At the journeyman or craftsman levels, since students exercise more control over their progress through diagnostic scenarios, assessment is quite different. In these modes, students

will select tests or replacements to perform using IMIS data but without specific IMIS recommendations. Because of this, an assessment report is envisioned comparing students' selections at each decision juncture with IMIS' choices. Embedded questions are much like apprentice level questions and feedback is immediate since questions are designed to focus and help clarify student thinking. Accuracy of question responses can be tracked and stored for later review by the instructor, supervisor or student. A sample Journeyman report is shown in Figure 10. The report indicates how IMIS ranks the student's choice for each action. In the example shown, the student selected the same option that IMIS recommended, therefore it received the highest ranking: "1". If IMIS considered the student's action to be less than the best choice, the score would indicate that by receiving a "2" or more for the action. Using IMIS' built-in event recorder, similar reports could be generated listing a student's steps, time spent completing the task, and any digressions or extra data requested to complete the task.

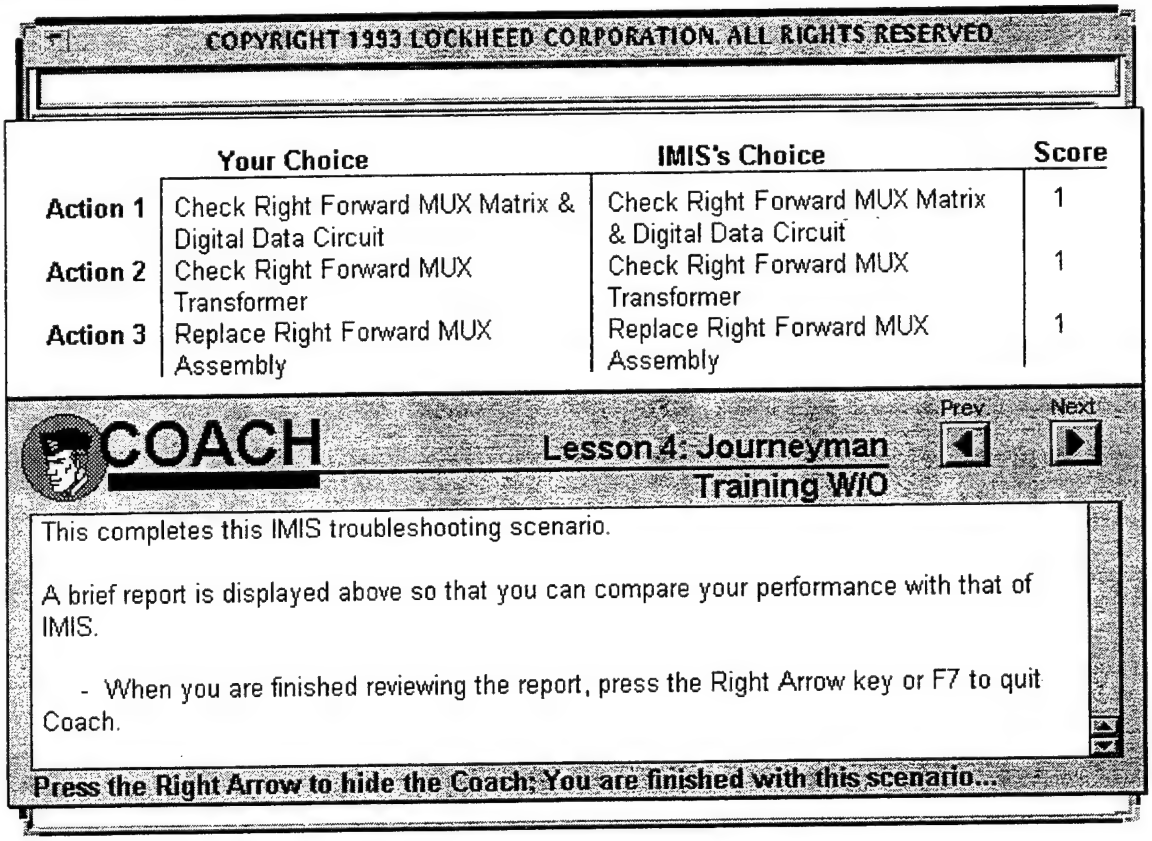

Figure 10. Journeyman Assessment Report.

A simple administrative report could be provided to list all diagnostic scenarios a student has completed by fault code, success expressed by how close the student's solution was to IMIS' recommended approach, and date the scenario was completed.

At times it may be desirable to provide students access to their training records to let them compare their performance to IMIS recommendations. This feature should be available to the student at *login* to COACH. To encourage study and use of IMIS procedures, it would be beneficial to allow students to select training scenarios themselves. In this case, COACH would randomly select a *faulty* component and allow the student to run the training scenario in any level

or mode.[21] These results would be only provided to the student and not added to their permanent training record. This would ensure that students do not perceive a penalty for independent practice. The supervisor would control this feature.

Authoring Training Scenarios

There is a capability for instructors or flightline supervisors to author training scenarios using COACH. Some authoring of system models can be made part of a COACH component of IMIS authoring. Essentially, there are two different approaches to authoring using IMIS. The first approach, *embedded authoring*, consists of specifying modifications to the current APS to allow instructors and supervisors to add training information to standard IMIS presentation screens. This authoring approach would create training that runs directly on the PMA. The approach has benefits and drawbacks. Certainly, instructors and supervisors are closest to those needing training and know the weaknesses to be addressed. An embedded authoring capability provides instructors and supervisors with tools necessary to construct or tailor training scenarios which directly address student needs. On the other hand, instructors and supervisors are usually the very people who have the least time available to develop training scenarios. Even if these potential authors were provided time to author, they normally do not have background, training, skill or experience in authoring. For example, although instructors and supervisors can frequently identify what is wrong, they do not know how to employ specific training strategies in remediating performance deficiencies. Unless IMIS' embedded authoring capability provides them with such tools, chances are that training will vary greatly and tend to be neither efficient nor effective. So, while modifying the APS is probably a low cost approach to authoring, it will probably have low training efficiency unless coupled with intelligent instructional design assistance.

The second approach, *independent authoring*, consists of making use of IMIS data to create instruction using any one of several off-the-shelf or developmental authoring systems.[22] This approach to authoring would create training which would not normally run as a seamless application with IMIS on the PMA. As with the previous approach, there are benefits and drawbacks. Using an authoring capability independent of IMIS allows IMIS data to be used by instructional designers in the creation of typical computer-based classroom training. The results of such an authoring approach should look and respond just like any other computer-based training lessons. This includes use of multimedia, appropriate instructional strategies, directed feedback and other features common to authoring packages. This approach is not without problems. Authoring would, generally, be removed from instructors and supervisors and performed by instructional designers either in an interactive courseware flight or perhaps, by contractors. This makes instruction at least one step removed from those who know what the problems are, i.e., instructors and supervisors. If an authoring system such as Step Writer (Norton, Thompson and Fleming, 1993) or a courseware generation system such as the eXperimental Advanced Instructional Design Advisor (XAIDA) were used (Hickey, Spector, and

---

[21] Students at apprentice level would be limited to that level unless specially authorized by their supervisor or instructor. Higher levels should have access to lower levels and modes for training.

[22] Commercial systems such as Toolbook, Authorware, or any other similar authoring package could be used to create instruction using IMIS files. At least two Armstrong Laboratory products, i.e., STEPwriter and XAIDA, could also be used. The advantage these developmental systems have over the commercial ones is their built-in instructional approaches.

Muraida, 1992), authoring could be more easily performed by instructors or supervisors, if they were given time. Furthermore, if capabilities of either of these systems were integrated with IMIS, it would allow subject-matter experts to take advantage of the built-in pedagogy to format and present instructionally sound IMIS lessons.[23] Perhaps an even more critical point is that unless there is an integration of pedagogically intelligent authoring systems and IMIS, training data will lose its link to the IMIS database and thereby its IETM source. This means that as equipment changes, training data which supports that equipment will not be automatically updated to keep pace with it. The importance of concurrency among a weapon system and its products, e.g., training, must be examined.

There may be a place for each of these authoring approaches within an IMIS training suite. By capitalizing on the useful features of each and minimizing deficiencies, IMIS authoring capability can be provided which creates efficient and effective training for any environment. So, if IMIS were being used on the flightline it would be possible for a supervisor to tailor COACH training scenarios for specific training needs using the APS. Furthermore, whenever block upgrades or new equipment were planned for immediate use, IMIS lessons could be created using one of the pedagogically intelligent authoring tools for just-in-time training. If IMIS were being used in technical school, these same two authoring capabilities could be used by an instructor. Typical everyday classroom lessons could be produced using pedagogically intelligent authoring tools. Practice learning about weapon system maintenance procedures or remediation of specific performance problems could be addressed using IMIS' APS.

Instructor Options

In order for COACH to meet the needs of real students and instructors in forging a mentor-apprentice relationship, it must allow instructors to tailor assignments for individual students and provide useful, timely performance and achievement information. In the best case, COACH could determine the focus of a troubleshooting scenario either on its own, as requested by a student, or under direction of an instructor. This provides substantial flexibility, and allows COACH to respond to differing needs of classroom technical training, individual drill and practice, and flightline OJT. Just as important, COACH can provide performance reports in a variety of formats to match student or instructor needs, and permit long term data collection and aggregation. These functions, as well as setting basic training system parameters will be accomplished through a system control interface.

COACH software must include an instructor interface for assigning scenarios to students or reviewing student performance or progress. There is little advantage to implementing COACH instructor interface features on the PMA alone. Instructor controls will probably need to be implemented on the PMA and PCs, as well as the MIW. Each training assignment will require the MIW to assemble appropriate TOs, test selection and training data for downloading to the PMA. Table 1 provides a brief overview of instructor controls, how they work, and the rationale that underlies each.

Access to the COACH instructor *menu* can be accomplished several ways. First, *Training Setup* might be added as a menu item under IMIS personnel, work order or options menus. Alternately, once a user registers as a qualified instructor the *Training Setup* option

[23] Further discussion of this will be found in the Conclusions section of this report.

might be offered automatically. As a an instructor, the user could select *Training Setup* to assign a work order to a student. Adding a *Training* menu option to IMIS' main menu is impractical since the current nine choices fill all available pull down menu space. Moreover, training setup procedures do not need to be available to most users, since most COACH users will not be instructors or supervisors who need to assign training.

Once in COACH's *Training Setup* component, the principal options are to assign training scenarios to students or review performance of an individual or group of students. Either of these procedures begins with selection of the individual or group of student records to be examined or to assign a training scenario. If instructors want to use a scenario for classroom training or demonstration, they can choose not to ascribe the outcome to any particular student. Otherwise, students are assigned training using the same IMIS personnel-listing dialog box used to assign work orders. After selecting a student, the dialog box would prompt: "Assign new training scenario or review completed scenarios?" If the instructor chooses to review completed training, IMIS would present another dialog box listing what lessons the student has completed by fault code, subsystem, and date completed. At that point the instructor could simply select the scenario and review student performance.

Table 1. Instructor/Supervisor Features.

Action:	**How to integrate with IMIS:**
Select student for training	Use personnel selection dialog box used to assign work orders.
Select training scenario	Use IMIS's work order assignment screen. Modify, adding buttons specifying: 1. that this is a training work order, not a real work order; and 2. level at which the assignment should be completed, e.g., apprentice, journeyman, or craftsman. Optional: Use *System Names* dialog box now used by IMIS to offer system selection under the *Display Training* option on *TechData* menu. IMIS would then display all fault codes associated with the selected subsystem.
Classroom demonstration	Use personnel selection dialog box to select *Instructor* mode. Select training scenario as above. When scenario is run, no permanent training record is created.
View student records	Use personnel selection dialog box to select student by name or number, then present a dialog box containing scenarios completed by fault code and subsystem. User presses *View* button to see selected report.
Print student records	Follow procedures to *View* student report on MIW, then use MIW report printing procedures.
Delete student records	Use the *View Student Record* option listed above. User presses *Delete* button to remove highlighted training record. Deleting a student through normal personnel deletion procedures could also delete all associated training records.

There are a number of ways an IMIS scenario could be selected for training. The simplest approach is to select a fault code, just the way an IMIS diagnostic session is initiated now. When the instructor enters a fault code, a particular subsystem is implicated, and a diagnostic scenario

is created by IMIS. An alternative approach may be for IMIS to list subsystems, e.g., heads-up display, inertial navigation system, etc. from which the instructor selects a subsystem for training. Next, the fault codes associated with the subsystem would be listed, from which the instructor would select an appropriate fault code. No matter which approach is used, COACH would present a list of the components contained in the plausibly faulty set for the instructor to designate one or more as faulty. A student completes the scenario successfully when he identifies, replaces, and runs an operational checkout on the selected component. Of course, the instructor could select the default choice, which is for COACH to select a *faulty* component randomly. In this case, even the instructor would not know which component is faulty until the scenario is completed. This could be particularly useful for classroom demonstrations, where the class has to solve the problem together. This could provide additional support for the mentor-apprentice relationship, as well as build group cohesion by enhancing collaboration, teamwork, and individual achievement.

Another task that instructors or supervisors must perform after creating a training scenario is to set the appropriate training level, i.e., apprentice, journeyman, or craftsman. Without an intelligent student model, it will be necessary for the instructor to determine which level is appropriate for students. For example, the instructor could specify journeyman level for a Fire Control Radar training scenario using fault code 94-61-AD. The next time the student-technician logs in to COACH, a dialog box would appear telling him a journeyman training scenario is ready. Once the student selects journeyman level, the scenario begins automatically. This concept is demonstrated in the COACH prototype software (see the appendix).

COACH: Training Context

COACH was conceived as a multiple context trainer. It was designed to function in a variety of situations including technical school, flightline OJT, in the ready room, or for self-study. To ensure that COACH is portable across contexts and platforms, hardware limitations must be considered. COACH should be easily transportable from PMA to desktop multimedia PC. Perhaps, more important issues to consider are human factors involved in the various training contexts.

On-the-Job Training

As FTDs are eliminated, technical training and formal OJT programs take on increased importance in ensuring adequate performance of flightline maintenance technicians. In the future it will be possible to conduct OJT using several new technological approaches. First, Air Education and Training Command (AETC) either has or is installing satellite downlinks at a number of bases. This satellite network will be used to deliver traditional classroom training courses and, more importantly, it can also be used for *just-in-time* training. In all probability, just-in-time training will be used to deal with critical maintenance issues such as aircraft block upgrades, new equipment, emergency action items or new procedures. As a second factor to consider, multimedia PCs are being installed throughout most Air Force organizations, including shops near the flightline. These PCs are being used for many purposes including providing technicians with access to electronic TOs and computer-based instruction opportunities. In addition to the PMA, these multimedia PCs could well be used as another means of presenting IMIS training scenarios. Finally, for the next few years, AETC's access to training aircraft for technical school, and the availability of spare aircraft for OJT will certainly continue. Using the

PMA, COACH could work well to provide training in any of these contexts. As a final note, in our opinion, we must caution that using COACH during actual flightline maintenance is not advisable. Flightline maintenance activities are frequently conducted under critical time restrictions since turning the aircraft around is normally a primary concern. Using any of this time for training may interfere with achieving that goal. Furthermore, technicians may not always be aware whether they are in a training mode or working on an actual problem, no matter how clear it may seem to designers of the system. We would suggest that use of IMIS in a training mode on the flightline be reserved until it is determined whether safety of flight and other such issues can be resolved favorably.

How would just-in-time training via satellite work? First, after receiving satellite training, technicians could rehearse procedures using the PMA with COACH. In fact, the PMA could provide a valuable way for remote distance learning instructors to assess student performance.[24] IMIS training reports could be easily uploaded to an instructional origination site. For example, the instructor located at the distance learning origination site at Sheppard AFB could see the results of students at Luke AFB shortly after completion of the exercise.

Continuation or recertification training could also be conducted using COACH. With IMIS, it may no longer be necessary to schedule formal meetings to conduct recertification. Instead, journeyman technicians could use the PMA or a PC to prepare for recertification. They could do this preparation either at home or in the ready room; the preparation time might be outside of duty hours or while waiting for their next work assignment. In any event, once ready for recertification, the technician would schedule a time for testing. The technician's supervisor still would not need to be present for testing if it were held at the base training office or another suitable place. Testing would consist of a scenario run on the PMA, or even a PC. After completing the test the student would return the PMA to the supervisor or base training center for evaluation. Supervisors could then review test results, see how long the technician took to prepare, and determine if the technician needed more training or was ready for recertification. This asynchronous mode of training may be accepted or preferred by students and supervisors who currently have to fit in scheduled training sessions around flightline demands.

Finally, technicians not working under time constraints to turn-around aircraft could run COACH while performing routine diagnostic work on aircraft in the hangar. In such a situation students may not be undergoing formal training, however, they can gain valuable insight into the troubleshooting process by following IMIS's DM expert. Such COACH features as embedded questions, assessment functions, and predicting results of tests can provide students a deeper understanding of what their mental processes should be like when troubleshooting. This approach also provides OJT supervisors an easy way to assess the readiness of technicians. As discussed earlier, use of COACH could severely affect efficiency of flightline maintenance, therefore, sufficient time must be provided to technicians using this approach. Normally, the most appropriate time for training troubleshooting strategies is just prior to performing diagnostic activities.

---

[24] Evaluation of student performance via a one-way video distance learning system has always been a limiting problem for that technology.

Technical School

There are a number of benefits associated with using IMIS during technical school. Troubleshooting has not been an extensive focus of technical school curricula, (Hicks et al., 1995), therefore, integration of exercises using COACH in technical school can serve two purposes. First, it can provide apprentices valuable early exposure to working with IMIS, a tool they must ultimately become familiar with. Second, COACH provides apprentice technicians experience with diagnostics early in their careers. This can help shape their thought processes towards productive troubleshooting techniques such as use of the half-split approach and elimination of functioning components. COACH can also be a valuable tool for instructors demonstrating aircraft subsystems and discussing the function and interrelationship of components. COACH can also provide apprentice technicians much needed experience working with TOs and performing test, replacement, and operational checkout procedures. We cannot emphasize enough COACH's potential to create *synthetic experience* for apprentice technicians; guiding them through procedures even before they have worked with an aircraft.

Another benefit of COACH in technical school classrooms is cost. As IMIS becomes the Air Force's preferred way to work, PMA devices will be readily available. Actual aircraft or flatboard simulators are expensive training luxuries and only a few students can work with them at one time. PMAs with COACH could serve a number of students simultaneously in diagnostic scenario simulation led by an instructor. With desktop PCs or PMAs, students could work independently during study periods while the instructor answers questions or directs learning activities. Use of COACH has advantages for instructors too. Instructors can help more students during their short time in technical school. Students will have an opportunity to complete more exercises and increase their exposure to aircraft subsystems. Throughout this process students will gain experience using IMIS, which will be their principal source of TO information and diagnostic advice. Just as important, they will learn valuable strategies to use when confronting elusive faults that published TO procedures do not resolve.

Issues of Acceptance

When any new instructional system is implemented, it can be threatening to users. Despite the fact that a well-designed, cohesive training application may ultimately increase technician efficiency, such systems frequently produce fear and resistance. Students familiar with traditional classroom training may be unsure how the new system may affect their performance. Instructors frequently speculate that new automated systems are aimed at replacing them. Managers are often concerned about how automated systems affect manpower slots. While such fears may be downplayed, nevertheless they must be dealt with prior to implementation or they can lead to failure. Despite the best intentions, if users feel a system is not in their own best interests, they simply won't use it, or, if forced to use it, will undermine it.

Acknowledging these realities, steps should be taken to carefully enfranchise various stakeholders by enlisting their support for any system being developed. In particular, system designers should consider several key ingredients in gaining support from students and instructors who will use the system. First, there is evidence that users should be consulted for their input during the design process. Systems development theory (Kling, 1991; Conner, 1985; Boar, 1984) and practical field experience (Kyng, 1991; Perin, 1991) both indicate that potential users of a system should be involved during early stages of design. Kyng (1991) advocates a

doctrine of "mutual learning" where designers teach users about the technological possibilities while users instruct designers in the specific tasks of their work. Perin (1991) discusses the problems created when systems are mandated for unwilling users. Different stakeholders naturally have different expectations for a system. While expert consultants might easily specify a competent COACH training system in terms of instructional technology and perceived needs of supervisors, instructors and students, there is no certainty that such a system would be accepted by Air Force training personnel or students. For this reason, it is important to demonstrate prototypes of the proposed training system and gather feedback from supervisors, technical school faculty, and a wide range of maintenance technicians from novice to expert. This process should begin shortly after preliminary design specifications are complete whenever implementation of the new system is decided.

Second, for COACH to be accepted in the Air Force training environment, members of the training community, i.e., instructors, instructional developers, and training administrators, must envision the new system as teaching the kinds of maintenance skills and knowledge they think are important. Kurland, Granville & MacLaughlin (1992) noted this in relation to their experience with the MACH-III trainer. They found some key functions that are standard in most intelligent tutoring systems, were not implemented in MACH-III because teachers viewed them as frivolous and not useful. IMIS can be used to teach various types of knowledge necessary for maintenance including procedures, mental models, troubleshooting strategies, and coordination processes. However, it is yet to be determined if the typical instructor will see this as valuable--certainly, they were never trained this way! For the most part, a person's concept of how to train is based on their own experience, i.e., how they were trained. Currently, technical school does not emphasize troubleshooting strategies or related component knowledge. This may indicate the need to show instructors the value of such knowledge before they are asked to embrace a system designed to teach it.

Another way to encourage acceptance and use of COACH by instructors and supervisors might be to secure a role for them in its use. This could be done by implementing COACH applications requiring supervisor or instructor intervention to direct scenarios, set learning goals, and interpret performance results. This approach strengthens the supervisor's and instructor's position and helps alleviate their fears of being replaced by a computer.

Finally, implementation of COACH on the PMA may help to enlist support of aircraft maintenance instructors once benefits of such a system are clear. Certainly, implementation of COACH provides valuable experience using the PMA as well as training diagnostic skills. Also, providing COACH training in technical school allows students to pattern PMA usage long before reaching the flightline. Integrating training with a job-aid provides new opportunities for contextualizing training. This could help students transfer knowledge from school to job more effectively. Finally, use of COACH provides a continuous lineage of training from technical school through OJT, and throughout a technician's career.

III. IMIS TRAINING

To place IMIS in a training context, it is best to examine training functions that system designers intended for IMIS. As a starting point, we reviewed the *System/Segment Specification for the Integrated Maintenance Information System (IMIS)*, 1993[25]. This document lists and briefly describes system requirements for IMIS. In it we searched for every mention of IMIS training functions. Throughout the rest of this section portions extracted from that specification (boxed text) describe IMIS training functions intended by the system designers. Following each description extracted from the specification is a discussion of what the function implies, i.e., whether that function is an application of IMIS to training personnel in maintenance skills, or if the function provides assistance or training on how to use IMIS or the PMA device. Our ultimate goal was to determine specific instances in which IMIS is used for maintenance training rather than training personnel how to use IMIS, i.e., our focus was on using IMIS to train maintenance technicians how to perform maintenance functions such as troubleshooting, procedural tasks, etc. Once the intended IMIS training applications were identified, an approach was formulated to determine which components of IMIS could be most useful for training, how training using IMIS should take place, who should be trained, and what each individual or group should be trained on.

MAINTENANCE TRAINING MODE

> 1.3.2.5 The IMIS will support sustaining and improving the competence of maintenance personnel. The IMIS will maintain records of training progress, skill level, and task qualifications of each individual maintenance technician, record performance data associated with maintenance activities, and assist trainers in identifying training needed to meet the needs of each individual and of the maintenance unit. The IMIS will serve as an aid to assist in training personnel to perform maintenance tasks and as a tool for training in the use of the IMIS. (p. 1-11)

In the maintenance training mode, the intent of the system's designers is for IMIS to perform three major functions: 1) maintain individual training and qualification data, 2) train personnel to perform maintenance tasks, and 3) train personnel in the use of the IMIS device, e.g., the PMA. The first two functions certainly fall into the category of supporting or performing *maintenance* training rather than specific *device use* training, therefore, they fall within the scope of researching IMIS as a training device. Each of these functions is an ambitious undertaking.

Qualification Data

In looking at IMIS for training, we must ensure that capabilities of the system can support suggested training applications. IMIS certainly gathers, stores, and makes use of various data in assigning probabilities to faults, providing directions to technicians, and performing other functions, therefore, its ability to gather training-related performance data is without question. Armed with such performance data, supervisors of all kinds, from shifts to squadrons, can identify individual or group deficiencies and arrange for appropriate training to mitigate these deficiencies. IMIS performance data also provides leaders with the ability to classify personnel

[25] Only the draft document was available at the time this report was written. Numbers next to section titles refer to paragraphs in that version of the document.

who are: ready for additional responsibilities, able to mobilize immediately (or within a short period), in need of special attention because of failure in a single or many different tasks, etc. If job performance were tied directly to pay and promotion, IMIS would be able to accurately report how well each individual is doing as compared to an objective standard as well as in comparison with his/her peers.

While performance data are one of the most appropriate sources for identifying training needs, there are problems associated with its use. Gathering and storing such data using IMIS will be a relatively simple task, however, individual performance data tend to be highly volatile. In short, personnel are immediately suspicious that any data gathered on their performance may be used for evaluation purposes. They are frequently apprehensive that data may be interpreted to their disadvantage rather than for what stated intentions were. Thus, protection of data becomes an issue. Furthermore, employees/airmen have ways of coping with what they may view as an invasion of their privacy. If accuracy is viewed as important, then speed will be sacrificed to attain flawless performance; if speed or quantity is considered important, then accuracy may suffer. Neither of these alternatives furnish the kind of results that were intended with IMIS.

Another problem with gathering performance data is the time required to develop a comprehensive view of technician competencies over a wide variety of faults. Performance data are traditionally generated over time as trainees deal with a variety of maintenance tasks. While a general picture of mechanical skills and comprehension of major systems may be formed quickly in this way, understanding diagnostic skills takes longer, e.g., until more unusual faults are encountered. One way to speed generation of these data would be for IMIS to simulate more complex diagnostic situations in order to evaluate technician performance.

The COACH application described herein demonstrates such a method of collecting qualification data. By completing a COACH-generated generic simulation, IMIS can determine the user's cognitive competence on less common troubleshooting, test or repair procedures. IMIS can be used to simulate unusual faults which a technician would rarely experience on the job. COACH can also generate numerous examples of typical faults. These long-term performance data could be combined to create a complete record of the user's cognitive understanding and maintenance skills.

Training Maintenance Tasks

IMIS greatest potential to train maintenance tasks lies in its technical data. Just as COACH utilizes IMIS technical data to create generic maintenance simulations to train troubleshooting strategies, using IMIS data for "dry runs" of maintenance procedures may be effective at familiarizing technicians with maintenance preconditions such as: tools, conceptual models of subsystems, equipment nomenclature, and locations.

There are two ways IMIS data may be used for training: with or without operational equipment. As an electronic performance support system (EPSS), it is reasonable to expect a certain amount of training will occur simply through repeated use with operational systems repairing real equipment faults. While the role of an EPSS is to guide technicians through an entire maintenance or repair procedure once a procedure has been performed several times, technicians will, in all likelihood, be less reliant on the EPSS for guidance and advice. In this sense, procedural training will naturally occur as a side effect of using IMIS for its intended

purpose--performance support. However, many of the most important training issues involve equipment that only rarely breaks down and maintenance procedures which are infrequently performed. In this situation, years of experience working with an EPSS still may not provide sufficient exposure to certain tasks to provide any useful training. In this case, the generic simulation approach outlined above in relation to COACH provides a useful way for technicians to gain experience as well as become familiar with the steps and caveats of a procedure without risking expensive operational equipment.

Using the IMIS Device

Most training on how to use the IMIS device, e.g., the PMA, can be accomplished through a standard on-line help system documenting the functions of each button and menu choice. This approach provides just-in-time guidance to the technicians as they work with the device. In addition to on-line help, a simple, self-paced tutorial could be developed which introduces technicians to IMIS functions. This tutorial might include simulations showing how menu selection operates, and provide overviews of principal data collection screens. Finally, a tutorial could run a simulated diagnostic session wherein it explains the typical screens, menus and dialog boxes encountered during testing and repair.

For overall effectiveness, IMIS device training should be accomplished in a way which reinforces use of IMIS as an *aid* to the human diagnostician's thought processes rather than as a replacement. Using IMIS should not relegate technicians to a passive role or long term performance and development of personnel competencies may suffer. This is a crucial issue, because the accuracy and reliability of IMIS dealing with real world faults is still to be tested. What is known is that certain unusual or non-duplicable faults may force IMIS into a *degraded* mode where its advice to technicians is limited. In this case, technicians must possess suitable diagnostic skills to continue troubleshooting without extensive advice from IMIS. Therefore, training using IMIS should stress troubleshooting strategies and contingencies for working in the absence of detailed advice, and ways for technicians to recognize when IMIS's recommendation may not be the best alternative, as well as training in PMA usage and procedures. A simple way to accomplish this may be to automatically display such a notice whenever IMIS enters its degraded mode. Supporting guidance might include a checklist of actions already performed and their outcomes, a menu of related TO's and technical data, a list of possible tests which have not been performed along with their predicted usefulness and required time, and generic advice regarding troubleshooting strategies for use with hard-to-diagnose faults.

IMIS PERFORMANCE CHARACTERISTICS

Maintenance Training Mode

> 3.2.1.1.5 The maintenance training mode supports the training of maintenance technicians by accessing external systems for computer-aided instruction and through the use of IMIS functionality and equipment in the development, administration, and delivery of maintenance training. The IMIS includes capabilities to allow maintenance technicians (with or without instructors) to familiarize themselves with and practice maintenance or diagnostic tasks, with or without weapon system mockups or the actual weapon system. The IMIS, as a training system, will be used within the maintenance organization to augment any existing Computer-Based Training (CBT) or Interactive Courseware (ICW) platforms currently in place or to be installed after the IMIS has been fielded. The IMIS will be used to present CBT or ICW supplied by other systems and create appropriate records of the training conducted in the event that other platform is available. Additionally, the IMIS supports task familiarization, prior maintenance task performance, practice in the performance of diagnostic tasks via simulated Off-Equipment scenarios, and monitoring and reporting on the quality of the IMIS utilization by the user. The tasks included in this type of training are the full range of On-Equipment and Off-Equipment maintenance activities, such as FLSE repair, how the IMIS provides prefilled data fields (based upon the aircraft tail number) or fills out a form, how to determine whether required calibration is overdue, reporting of emergency conditions, and other possible scenarios. The IMIS also supports maintenance training instructors by allowing them to set up cases for a simulation, observe and interact on-line with the training of an individual, and interact with simulations to add special cases in real time (e.g., how to operate or service a piece of Aerospace Ground Equipment (AGE)). (pp. 3-66 - 3-67)

IMIS designers envision an IMIS that is fully integrated into existing and future computer-based training systems. They believe IMIS should be able to: 1) access external training data and record keeping systems, 2) author instruction, 3) present instruction, 4) simulate various maintenance tasks, and 5) allow for real-time instructor interaction with the trainees. While these are worthy goals, it may be impractical to attempt some of them given the state of development of competing instructional design and delivery platforms.

Accessing External CBI Systems

For example, the designer's goal of using IMIS to present CBT or ICW supplied by other systems may not be feasible if future implementations of IMIS continue to run in a UNIX environment. The great majority of multimedia instructional development and delivery systems in use rely on Microsoft Windows software as their runtime environment. It is likely that this trend will continue due to the substantial difference in cost between fast, portable UNIX platforms and operating systems versus multimedia laptop PC's running Windows. In addition, a number of maintenance training authoring systems are presently being developed by the Armstrong Laboratory[26], all of which are designed to run on PC-compatibles. If future versions of IMIS run under Windows, this goal may become practical. There are, however, other issues related to instructional presentation through IMIS which will be discussed below.

---

[26] The experimental Advanced Instructional Design Advisor (XAIDA), GAIDA, StepWriter, and MITTWriter are various PC-based instructional authoring tools being developed by various branches of the Human Resources Directorate, Armstrong Laboratory. Only RIDES, which is a maintenance simulation package being developed by that organization, operates in a Unix environment.

A more practical goal for IMIS is to access external training support systems such as AETC's Advanced Training System (ATS). Technical school records from student training sessions conducted on IMIS and other training delivery systems could be stored centrally in ATS. The concentrated data which results can be used by maintenance instructors to develop training needs profiles for each student and to individualize training programs. A direct connection between IMIS and ATS may also allow long term task performance outcomes to be compared to training performance data to help spot students who require instruction on particular tasks, or who continue to perform poorly after considerable training. In this case, IMIS's ability to accurately collect real-world task performance data may substantially enhance the ATS potential to provide timely training and advancement recommendations. A similar capability for storing and utilizing training data from OJT should also be identified so that the same kinds of functions can be performed by supervisors as the ATS allows technical school instructors.

Instructional Authoring

Another goal of system designers is that IMIS be used to develop maintenance training. This may be practical depending upon how broadly the statement is interpreted. While we believe it is possible to author text and graphic instruction similar to the COACH prototype, we did not see evidence of any advanced instructional capabilities in IMIS. The instructional authoring potential of IMIS is largely dependent on the capabilities of its APS. Due to the proprietary and developmental nature of IMIS APS, we were unable to work with the software or review detailed functional specifications. Our conclusions, therefore, are drawn from a review of the capabilities manifest in IMIS prototype MIW and PMA software. Both applications demonstrated interface elements common to CBT software--pulldown menus, buttons, mouse control, graphical dialog boxes, presentation of text and graphics--but not many of the underlying pedagogical structures or media support tools that are common to CBT development systems. Multimedia authoring systems provide tools for creating rich interactions, student modeling, playing video and audio, animating screen elements and providing dynamic branching and feedback to user input. While it would certainly be possible to integrate these kinds of tools into the IMIS, the practicality of such an effort is questionable given the variety of commercial off-the-shelf authoring systems already available and the specialized maintenance training development systems being created by Armstrong Laboratory. What may make more sense would be to make IMIS technical data available to external training development and delivery systems.

Instructional Presentation

There are a number of problems associated with the use of the PMA or any EPSS for training delivery. Many EPSS devices--like the prototype PMA--do not provide the multimedia features that an increasingly sophisticated student audience has come to expect. This makes engaging the learner and maintaining attentiveness difficult. Users expect to get just-in-time information from the EPSS device, and for this they will sacrifice the comfort, color, and amenities of a desktop system. But, we suspect it is unlikely that most users will actively engage in a training or recreational dialog with such a system for any length of time.

Even if color, audio, and other multimedia features are added to an EPSS, a number of questions remain about the psychology of using a job support tool for training as well. Formal training sessions have traditionally implied a diversion from routine task performance.

Participants are able to move their cognitive focus away from job tasks and enter a learning mode, but such a separation of the cognitive loads of the job and those of learning may not occur if formal training is delivered on the same tool routinely used on the job. The cognitive effects of using EPSS devices for delivery of formal training remains an issue for experimental research.

Another question that should be explored is the potential for such training, if available at the job site on an EPSS, to distract from task performance. If users can choose between a dry recitation of procedural steps and a rich interactive experience, one might postulate that task times would increase and accuracy decrease as users become more involved in the lesson than in the primary physical task at hand.

Task Simulations

One situation for which use of the IMIS device for instructional presentation does make a great deal of sense is with apprentice technicians as a practical way to simulate task performance prior to working on the flightline. In this situation, the TO presentation system in IMIS could probably perform adequately without addition of any instructional features since apprentice technicians in the classroom and flightline are closely supervised. However, addition of COACH might be used to explain the purpose of steps and provide scaffolding for less experienced technicians. As technicians gain experience, appropriate use of IMIS's simulation capability might include: rehearsing a tricky procedure before task performance or when turnaround time is tight, previewing procedural changes that result with block upgrades or new subsystems, practicing new tasks prior to certification, and assessing performance. In all cases, however, task simulation should probably be used as part of a formal training course along with human supervision. It is unknown how much cognitive knowledge or skill would be transferred through task simulation, but the danger exists that a technician could grow overconfident and subsequently attempt tasks on operational aircraft without sufficient consultation of the TO.

Instructor Interaction

The final goal of the IMIS designers for the Maintenance Training Mode is that the system, "supports maintenance training instructors by allowing them to set up cases for a simulation, observe and interact on-line with the training of an individual, and interact with simulations to add special cases in real time...". COACH's approach to instructional simulations postulates instructor selection of diagnostic procedures for study and choice of the specific faulty component. Such a broad range of individual tailoring of instruction is rarely found in single purpose simulators, let alone job-aids adapted for training. While the IMIS design document does not clearly specify the kind of interaction with simulations designers envisioned, this requirement poses several interesting technical questions. Did designers intend for instructors and supervisors to interact with simulations while technicians were actively involved with them? If so, this implies PMA networking to allow instructors or supervisors to work at an instructor control console and observe individual training. While this kind of expensive real-time instructor monitoring of student performance is possible on a PC network, it tends to defeat the purpose of the PMA as an independent job-aid. This report already describes adequate asynchronous methods for instructors and supervisors to interact with IMIS by building COACH scenarios, viewing student records for individuals and classes, and selecting the kind and number of scenarios each student would study. While IMIS will have a RF link with logistics parts information, extending that link to include real time observation of training may not be desirable

or cost-effective. In our opinion, real time interaction with IMIS training is impractical and unnecessary. The asynchronous interaction provided by COACH should be more than adequate for all instructor and supervisor needs.

IMIS Training

> 3.3.7.2.10 The IMIS will include support for both formal and informal training of IMIS operation. The formal training will be supported by system documentation and all necessary instructor and student materials. Operators will be trained to criterion performance on a standard task set. Informal training will also be supported by context-sensitive on-line help and indexed help. The following sections list the IMIS human engineering requirements related to training.
>
> a. The IMIS shall provide embedded computer-based training to teach IMIS operation in support of both formal and informal training.
>
> b. Formal training shall support the acquisition of user skills for personnel of varying previous exposure to computers.
>
> c. The IMIS shall be designed such that minimal formal training will be required. (p. 3-125)

Clearly, IMIS designers never envisioned using the job-aid as an independent training tool. The human engineering requirements related to training that they listed focus on using embedded computer-based instruction to train IMIS usage. While it is certainly important that technicians can be easily trained to use the PMA, there are other uses for a training capability embedded in IMIS that extend its effectiveness beyond job-aiding. This report has documented some of these additional training uses of IMIS. Complex machinery can fail in complex and unexpected ways. It is unlikely that any computer system will perform consistently in every diagnostic situation. Rather, it will likely fail on faults difficult to duplicate or diagnose. For this reason, technicians should be familiar with both the capabilities and limitations of IMIS. Furthermore, technicians should be able to fall back to tested procedures for troubleshooting whenever placed is such situations. Without training specifically designed to prepare them for such a contingency, technicians will be unable to function adequately when faced with these difficult situations. Contingency troubleshooting procedures will provide technicians with strategies for continuing advanced diagnostics in the event IMIS cannot provide a solution. The goal of adding troubleshooting training to IMIS is to help ensure that technicians use IMIS as an assistant rather than becoming totally reliant on IMIS recommendations.

Formal Training & OJT

> 3.6.2 Formal training on the IMIS is required in preparation for initial deployment and to support USAF follow-on training requirements. OJT is required to maintain proficiency and to attain higher Air Force Specialty Code (AFSC) skill levels. The following sections outline the requirements of the IMIS training program.
>
> a. The IMIS training program shall be implemented using guidance provided by United States Air Force (USAF) Manual AFM 50-23 and MIL-STD-1379D.
>
> b. Formal training shall satisfy two basic requirements:
>
> 1. Use of the IMIS in support of aircraft maintenance.
> 2. Maintenance of the IMIS equipment itself.
>
> c. Maintenance training shall be in concert with the approved IMIS maintenance concept.
>
> d. Training shall be structured for FCS and for DSS contingency scenarios. (p. 3-145)

Again, as described above, the designers of IMIS did not envision using IMIS for anything beyond delivering training on its own use and maintenance. This shortsighted view

fails to take into account the wealth of maintenance diagnostic information available in IMIS which could easily be tapped for training technicians in troubleshooting. In any event, we see no reason that the IMIS training capabilities envisioned in this report cannot be simplified to handle training IMIS use in support of aircraft maintenance and in support of maintaining IMIS equipment. While the IMIS software has been designed to be relatively intuitive and easy to use, it is reasonable to assume that users may require a basic introduction to IMIS functions, keyboard, and on-screen controls. For novice computer users in particular, brief formal training may be required on using the keyboard and joystick, responding to a dialog box, navigating through screens and menus, and connecting to power and external systems such as the MIW or 1553 bus interface. Common IMIS device troubleshooting and preventive maintenance procedures should be a part of any formal course.

MIW Training

> 3.7.1.3.2 The training function shall support two major types of training: IMIS-usage training and maintenance training. For maintenance training, the training function of the MIW shall provide different types of training, including standard/simulation training and On-the-Job Training (OJT). The training function shall also provide training administration capabilities such as tracking of the training progress of individuals to support instructor evaluations. (p. 3-161)

System designers looked to the MIW as being the IMIS component capable of providing maintenance training rather than merely training use of IMIS devices. As we mentioned before, the practicality of integrating training development and delivery functions into IMIS software needs further clarification. Furthermore, using the MIW to develop or deliver maintenance training is a questionable choice. Such high priced UNIX workstations do not have the authoring capabilities of most multimedia PCs using commercial software. In fact, as described in this report, most of the authoring, administrative and training functions necessary for the IMIS system can probably be performed efficiently on PCs. If IMIS training software can be implemented on a multimedia PC, the next logical step is to utilize the PC for double duty, running training developed by a variety of mature commercial systems. This kind of IMIS training development and delivery capability could be enhanced significantly and made even easier by developing mechanisms that allow authoring systems to access IMIS technical data for use as a media resource.

PMA Training

> 3.7.2.3.2 The training function for the PMA shall have two capabilities. These are familiarization with use of the PMA and on-the-job training. (p. 3-175)

These are two realistic goals for training use of the PMA. PMA familiarization training will probably consist of general information on use of the PMA in IMIS diagnostic procedures, and methods of operating the PMA especially how to access specific IMIS functions. While formal classroom training is probably required initially, the PMA should be able to provide stand alone operational training to users by means of its on-line help system which documents functions of each button on the keypad and how various menu options, dialog boxes, and other on-screen functions can be accessed and operated. Because of the PMA's size and portability, it will be feasible to use it in formal classroom training. The only limiting factor in using the PMA in formal training programs will be the number of PMAs available.

Extensive use of the PMA on the flightline makes it a valuable component for OJT. This report has already pointed out potential problems associated with using IMIS for flightline training, namely, that flightline maintenance is conducted under critical time restrictions, and using repair time for training may interfere with maintenance efficiency or effectiveness. In addition, technicians may become confused whether they are in a training mode or working on an actual problem. As long as these issues can be resolved, using the PMA for OJT should be acceptable as long as it is controlled properly. Most PMA interventions during OJT should probably be limited to advice directly related to the procedure underway. In other words, primary use of the PMA should be as a job-aid.

AIP Training

> 3.7.3.3.2 The training function shall provide training and assistance to technicians to access the AIP. This shall include familiarization training in use of the AIP. Due to the severe restrictions on the airborne equipment, any other training shall be extremely limited if included at all. p. 3-184.

The Aircraft Interface Panel (AIP) is a repackaged PMA integrated into the aircraft chassis (Wampler, Gunning, Wynkoop, Quill, & Moorman, 1993). The AIP collects BIT information from aircraft systems to improve fault data collection and provide primary diagnostics. It includes a MIL-STD-1553B bus interface to which the PMA can be connected to provide an interface to the avionics bus of an F-16, Block 40. The AIP is nearly identical to the PMA in functionality, though it lacks the PMA's messaging services, RF radio link, and, most important, portability. AIP familiarization training should probably focus on 1553 connection procedures and basic AIP functions for self-diagnosis and BIT reporting. Since the AIP is not portable, i.e., it is an integral part of the aircraft, use of the AIP for training is not advisable.

IV. CONCLUSIONS

Operational use of IMIS will provide new opportunities to integrate maintenance training into a technician's career path. Resources provided by IMIS through its CDM and DM algorithm constitute a database with great instructional potential. As with any new instructional technology, IMIS must be carefully applied to specific training needs to be successful. IMIS will not be a panacea for all training needs because of the limitations pointed out in this report. IMIS training capabilities should be carefully matched to instructional requirements so they can provide the greatest benefit to the Air Force.

Appropriate Content

Since IMIS software design focuses on the maintenance diagnostic process, its natural focal point should be on diagnostic procedures and troubleshooting strategies. Interestingly, Hicks et al., (1995) identified training troubleshooting tasks as a primary need in Air Force maintenance. As they noted, as many as 30% of faults could not be accurately diagnosed using existing paper-based TOs. Furthermore, they reported less than adequate training in diagnostic strategies for use when TO guidance is insufficient. Expert troubleshooting results from a combination of training and long term experience. IMIS has the ability to provide explicit procedural guidance and diagnostic guidance. As such, IMIS appears to have potential to provide compressed synthetic troubleshooting experience during initial training and throughout a maintainer's career. The same study also identified procedural training as a strong need. While

existing paper TOs and IMIS both provide step-by-step direction through testing and replacement procedures, technicians must count on experience to be sure that tests are accurate, that components are installed correctly, and that cautions and warnings are heeded. IMIS' ability to simulate test and replacement procedures should find practical application in both technical school and OJT training environments.

Training Approach

The instructional approach and training metaphor used in any training device are important. Hicks et al., (1995) suggested cognitive apprenticeship as an effective way to teach the knowledge and skills applied during troubleshooting. Cognitive apprenticeship training is characterized by realistic problem-based learning during which students exercise skills under the direction of a master technician. Because of the nature of this training approach, i.e., one-on-one, conducted under the intense demands of the flightline environment, it is rarely practiced. This training approach may not always be appropriate, since flightline technicians are under pressure to diagnose problems and turn aircraft, which can limit time to spend on instruction. Initially, cognitive apprenticeship training provides extensive support for novices and then gradually withdraws this support as novices progress to mirror the assistance given by a master. In human apprenticeship, novices receive extensive initial direction and oversight from a mentor. As technicians progress to journeyman, the mentor intercedes less often, only providing direction on new, unusual, or unfamiliar procedures. Finally, when apprentices gain experience and skills, the mentor's role is as consultant or advisor. Implementation of COACH should follow the same approach, since it effectively develops mental model knowledge and procedural experience, while emphasizing apprentice self-reliance and problem solving skills building the self-confidence required for craftsman performance.

Training Environment

While cognitive apprenticeship can provide synthetic experience needed to build troubleshooting skills, there are questions regarding its appropriate environment. Although technicians may use IMIS during all phases of their careers, we suspect the application of training using the PMA should be carefully controlled. As a job-aid, the PMA is intended for independent use by technicians under limited supervision. Using the PMA for training with limited supervision raises the possibility of misinterpretation and confusion. While measures can be taken to make instruction distinct, students may still confuse actual with simulated faults. For these reasons, we believe IMIS training is best applied in technical school and formal OJT rather than independent maintenance sessions.

Limitations of IMIS Equipment and Software

There are questions regarding use of IMIS hardware and software for training development and delivery. Much computer-based training relies on delivery systems with sophisticated multimedia features such as true color displays, stereo audio playback, and digital video presentation. Consumers are becoming increasingly more sophisticated. Most would no more accept text-based page-turner training on a monochrome screen than they would buy a black and white television. The IMIS APS does not feature multimedia authoring capabilities. In fact, some instructional interventions recommended involve changing the way IMIS presents information. In its current form, the APS can be used to author some elementary training

interventions, but the bulk of IMIS training requires a more elaborate authoring capability than the APS.

There are also questions about the suitability of IMIS hardware for training delivery. For example, the prototype IMIS PMA is severely limited for media presentation. It cannot provide audio, or play video at acceptable rates. The PMA uses a monochrome liquid crystal display, and a character-based joystick for cursor control. These defects constitute impediments to successful instructional design and presentation. If the PMA software can be successfully implemented on multimedia PCs, these problems will be alleviated. The MIW includes many features typical of multimedia computers. It has a color screen and mouse control, and is powerful enough to play dynamic media resources such as audio and video. However, the MIW is an expensive UNIX workstation -- a device not normally used for training development or delivery. Finally, the MIW and PMA hardware will be in high demand for use on the job, therefore, trainees could realistically expect little instructional time if training is linked with IMIS hardware. It would appear that IMIS training hosted on a PC is the most suitable way to integrate IMIS into training.

Recommendations

Given these concerns, researchers must explore the potential of making IMIS data available to training development and delivery systems. The IMIS database clearly has a great deal of value as an instructional resource. At issue is the most appropriate way to access and present IMIS data to maximize training effectiveness while reducing or eliminating risks to operational equipment. The research team has already begun looking into means of accessing IMIS data for use with commercial authoring systems. If feasible, this could provide a number of advantages. First, it would enable specialized IMIS equipment to be used as a diagnostic and logistical job-aid. Second, it would allow instructional designers and developers to access existing, verified technical data rather than recreating data from paper TOs or other sources with the risk of inserting new or perpetuating old errors. Finally, it would allow instructional developers to take advantage of the instructional capabilities of multimedia training systems. Essentially, the focus of research should shift from making use of the IMIS hardware and software, to making use of the wealth of information contained in IMIS for training.

REFERENCES

Boar, B. H. (1984). *Application Prototyping*. New York, John Wiley & Sons, Inc.

Bresee, J.S. & Greenlaw, D.R. (1992). Cost efficient maintenance training through cognitive fidelity. In *Proceedings of the 14th Interservice/Industry Training Systems & Education Conference*, San Antonio, TX.

Collins, A., Brown, J. S., & Newman, S. (1989). Cognitive Apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*. Hillsdale, NJ: Erlbaum.

Conner, D (1985). *Information System Specification and Design Road Map*. Englewood Cliffs, NJ, Prentice-Hall.

Cooke, G., Maiorana, N., Myers, T., & Jernigan, J. (1991). *Integrated Maintenance Information System Diagnostic Module (IMIS-DM): Version 5.0.* (Report No. AL-TP-1991-0016), Dayton, Ohio: Wright-Patterson AFB.

General Dynamics, Electronics Division. (1993). (DRAFT) *System/Segment Specification for the Integrated Maintenance Information System (IMIS)*. Document No. 9001608D, Contract No. F33615-88-C-0024, for Armstrong Laboratory, Human Resources Directorate, Wright-Patterson AFB, OH.

Gott, S.P. (1988). Apprenticeship instruction for real-world tasks: The coordination of procedures, mental models, and strategies. In E. Z. Rathkopf (Ed.), *Review of research in education*, Volume15, (pp. 97-169). Washington, DC: American Educational Research Association.

Gugerty, L.J. (1994). *Training Applications of Non-Diagnostic Intelligent Tutoring Systems*. (Report No. AL/HR-TP-1994-0026), Brooks, AFB, TX: Armstrong Laboratory, Human Resources Directorate.

Hickey, A.E., Spector, J.M. and Muraida, D.J. (1992). *Design Specifications for the Advanced Instructional Design Advisor (AIDA)*, AL-TR-1991-0085. Brooks AFB, TX: Armstrong Laboratory.

Hicks, K., Gugerty, L., Young, S., Walsh, W., Reiners, A. & Arnold, E. (1995). *Training Situation Analysis for Flightline Maintenance Training: Implications for IMIS.* (Report No. AL/HR-TP-1995-0014), Brooks, AFB, TX: Armstrong Laboratory, Human Resources Directorate.

Kling, R. (1991). Cooperation, coordination and control in computer-supported work. *Communications of the ACM,* 34, 12, 83-88.

Kyng, M. (1991). Designing for cooperation: Cooperating in design. *Communications of the ACM,* 34, 12, 65-75.

Kurland, L., Granville, R. & MacLaughlin, D. (1992). Design, development, and implementation of an intelligent tutoring system for training radar mechanics to troubleshoot. In M. Farr & J. Psotka (Eds.), *Intelligent instruction by computer.* Philadelphia, PA: Taylor & Francis.

Link, W. R., VonHolle, J. C., & Mason, D. (1987). *Integrated Maintenance Information System (IMIS): A maintenance information delivery concept.* (Report No. AFHRL-TP-87-27). Dayton, Ohio: Wright-Patterson AFB.

Norton, J.E., Thompson, D.F. & Fleming, J.L. (1993). *Step Writer Final Report: Development and Delivery Tools for Procedural Training.* (Unpublished technical report), San Antonio, TX: Armstrong Laboratory, Brooks, AFB.

Perin, C. (1991). Electronic Social Fields in Bureaucracies. *Communications of the ACM,* 34, 12, 75-82.

Thomas, D.L. (1995). *Integrated Maintenance Information System: User Field Demonstration and Test Executive Summary*. (Report No. AL/HR-TR-1995-0033), Dayton, Ohio: Armstrong Laboratory, Wright-Patterson AFB.

Wampler, J.L., Gunning, D.R., Wynkoop, C.E., Quill, L.L. & Moorman, L.L. (1993). *Human Computer Interface Specifications (HCIS) for the Integrated Maintenance Information System (IMIS)*. (Report No. AL/HR-TP-1993-0035), Dayton, Ohio: Armstrong Laboratory, Wright-Patterson AFB.

APPENDIX

COACH Demonstration Lessons

This appendix contains screens from the prototype COACH demonstration lessons. The examples illustrate the particular types of lessons and level of instruction found in COACH. A brief discussion of what is contained in the appendix follows.

Apprentice Lessons

The apprentice level of COACH provides an introduction and three types of lessons. The introduction and first two lessons are designed to be run initially when students enter training using IMIS. The third lesson type involves use of diagnostic scenarios. This type is intended for repeated use with many different fault codes. COACH apprentice level is most suitable for use during technical school, and perhaps during the first few days of flightline OJT. Maintenance technicians should use the apprentice level to gain experience with diagnostic and maintenance procedures for a variety of faults, including ones they might not normally see everyday or ones which only occur when an aircraft is severely damaged.

The COACH introduction is offered when a student logs on. Once this lesson has been completed, the introduction option will not reappear unless the student quits and restarts COACH.[27] The introduction points out the features of the COACH presentation window and explains navigational controls. For most users, running the introduction once followed by practical exercises using COACH will be sufficient. If there has been a significant period since the last COACH session, users may require a brief refresher on system controls.

Lesson one explains specialized terminology used by troubleshooters. Like the rest of IMIS, the presentation is text-based with some graphic support. Where practical, it defines terms and provides a brief example. Like the introduction, this lesson is meant to be run only once. Presentation of a standardized set of terminology is obviously important in terms of creating a solid basis for student learning in later lessons. Introduction of a standard terminology for troubleshooting also creates a departure point for conducting discussions of troubleshooting strategies and procedures. Moreover, teaching maintenance technicians standardized troubleshooting terminology provides them with a solid foundation for discussion of troubleshooting problems throughout the rest of their career. Hopefully, this will encourage a climate of collaboration among technicians and encourage them to pool resources and expertise in diagnosing unusual faults.

The second apprentice level lesson provides an explanation of a generic seven-step troubleshooting approach which describes the steps required to isolate and diagnose nearly any single or multiple fault. The seven-step troubleshooting process is laid out as a flow chart, similar to the flow diagrams in fault isolation charts that students are already familiar with (see Figure 6). Each step in the procedure is introduced and explained. Concepts are made clear by explaining them in terms of troubleshooting a common ignition problem with an automobile. By explaining each step using such a common and easily understood problem, COACH makes the application and intent of each step in the process obvious. In later lessons, COACH will relate each of these steps to the actions taken by IMIS' DM during troubleshooting. While the content of lesson two is fixed, some students may need to run through it several times before they fully

---

[27] Control over the introduction may be a student defined variable, e.g., after seeing the introduction once, a student may choose not to see it again.

grasp the troubleshooting approach. The lesson makes use of COACH's extended presentation window to display supporting graphics, and provides a glimpse of a simplified mental model.

A solid understanding of the diagnostic process used by IMIS, and expert troubleshooters in general, will help technicians better comprehend the steps they will be taking using IMIS. Eventually, this will help them make intelligent predictions about the next logical step to perform when diagnosing faults for which paper-based TOs do not provide obvious solutions. This lesson builds on the concepts, terminology and approaches taught earlier and provides practical examples of their application. The lesson applies problem solving steps in the same order as the IMIS DM, and explains various branching possibilities based on outcomes of a test or replacement. This forces technicians to think about the range of options yielded by positive or negative results. Finally, lesson two explains the high-level troubleshooting strategies of half-split and elimination. For example, a technician picks a test whose results will allow the elimination of a number of components no matter what the results are, thus reducing the plausibly faulty set substantially with each test or replacement conducted. Simple student interaction is integrated into lesson two, e.g., students are asked to identify components that can be eliminated based on success or failure of the test conducted.

In the third lesson, the IMIS DM leads students through realistic troubleshooting scenarios, recommending specific tests and replacements and asking students to conduct various tests or operational checkouts. Theoretically, this lesson could be run in the context of any fault code, component or subsystem which has been programmed into the CDM. This lesson, a COACH template, works effectively in a number of ways. First, students can select a specific component to be *faulty*, then IMIS shows them the range of fault codes which could be caused by the faulty component, and allows students to review procedures for diagnosing and repairing each. Second, an instructor can select a particular fault code implicating a set of plausibly faulty components, and the testing and replacement procedures students should work with. In this case, the *faulty* component could be randomly selected by IMIS. Such a scenario provides students with focused practice on fault isolation in a specific subsystem or component. Third, using the COACH template, IMIS could function in a classroom environment with a flatboard simulator containing a *faulted* component. In this scenario, students would not know which component was faulty. Success would be measured by eventual diagnosis of the planted fault. Finally, a COACH lesson could be run under guidance of a supervisor during OJT. In this environment COACH would explain the steps being followed by IMIS to isolate the fault.

Using COACH, students operate in a learning mode rather than trying to work through problems on their own. IMIS selects tests and repairs and COACH explains the rationale for each. This is functionally equivalent to a traditional apprenticeship where the apprentice first observes at the master's side, asks questions and listens to explanations. Eventually, the apprentice gets to try his or her own hand. There are significant differences between working with COACH and human apprenticeship. For example, students using COACH with an aircraft or flatboard simulator, actually conduct a number of common procedures such as operational checkouts and component tests, while an apprentice with a human master would probably observe performance of these tasks until the master was certain that the apprentice was ready. Conversely, while apprentices of human masters are able to ask questions which are general or off the track, students working with COACH are restricted to asking questions about the information COACH is designed to answer. Thus, work with COACH may be more focused,

and have fewer digressions than human apprenticeship, however, there is also less opportunity to ask questions about related peripheral or background knowledge. Nevertheless, running through a variety of faults with COACH should provide students with a great deal of synthetic experience -- both practical (as in conducting tests and replacements with a simulator or aircraft) and theoretical (as in understanding the process by which half-split tests and replacements are selected).

Journeyman Lessons

The journeyman level of COACH is based on simulated diagnostic sessions just like the apprentice level. In the journeyman level, fault codes define the IMIS diagnostic session just as they do when IMIS is used as a job aid. Like the apprentice level, the *faulty* component is instructor selected or randomly chosen by the COACH. The diagnostic procedures followed are the same as working with IMIS to diagnose a fault, however, in the journeyman level, the student takes on a more active role. For example, in the apprentice level, the IMIS DM selects tests and replacements, then COACH explains the rationale to the student on the basis of fault probabilities of various components, parts spanned by different tests, and time required to perform the procedures. All of this information is related to the goal of selecting logical half-splits to eliminate the maximum number of functioning components with each test or replacement choice. During journeyman level diagnostic scenarios, students must select each test or replacement by applying the logic learned during apprentice practice. To verify that students understand the basis for their decisions, COACH asks questions regarding components they expect to be eliminated by a test, or how important each factor, i.e., time to test, failure probability, availability of replacement parts, is in selecting the test.

The principal extension to IMIS software required to accommodate journeyman level is the ability to randomize presentation of recommended tests and replacements. Normally, IMIS rank orders from best to worst possible tests or replacements that might be performed at a given point in troubleshooting. It accounts for such things as time, probability, parts availability, and other logistical factors. To help students develop troubleshooting skills, the journeyman level should have IMIS present possible actions in a random order and suppress display of recommended tests, i.e., best action, on the menu bar. When confronted with this, students must analyze on their own various factors such as failure probability, time to test, parts spanned and parts to be eliminated before selecting a test. Choices are eventually compared to the DM recommendations to determine relative expertise. At each decision point, students choose the test thought to yield the most information. When a test is conducted, COACH asks the student to predict which parts will be eliminated. This allows student choices to be compared to IMIS recommendations to establish an overall estimate of their knowledge and the implications of their choices.

While journeyman level COACH requires students to take an active role in making troubleshooting decisions, it provides immediate feedback about the efficacy of the choice. Thus, if a student chooses a poor test or repair, COACH compares it to IMIS' recommendation and explains to the student why the selected test is not the best choice. The student can stick with the original choice to see how it affects the number of steps required to solve the problem[28]

[28] In some cases, a lucky mistake could actually yield improved performance on a particular scenario.

or turn to IMIS's *possible actions* screen to select a different test or replacement. Such feedback is very important since it allows students to modify their behavior as they work rather than reviewing mistakes later when scenarios are not as fresh. This approach is parallel to the mentor watching while the apprentice works on a task while and offering corrective hints at strategic junctures. It also allows students to experience what following their own choice might lead to, regardless of the consequences.

Craftsman Lessons

COACH craftsman level is also based on diagnostic scenarios, however, at the craftsman level IMIS DM provides no assistance. Students progress through diagnostic scenarios selecting tests and replacements from the list of possible actions. Students can access logistical data and performance support information provided by IMIS as an aid to their decision making. In this case, COACH does not provide immediate feedback on how good a selection is until after the diagnostic scenario is completed. For this reason, craftsman level may be appropriate for testing and certification.

In a typical exercise, a fault code is entered to initiate the scenario. The *faulty* component may either be specified by the instructor or supervisor, randomly selected by COACH, or be a malfunction from a flat-board simulator or aircraft. Students begin the scenario as any other IMIS work order, by selecting the *Troubleshoot* option from the *DIAG* menu. IMIS provides students access to support materials. Students select each test or replacement, perform the test if necessary to obtain results, and enter results into IMIS yielding a new list of possible actions. When the scenario is completed, IMIS prepares a report comparing the student choices at each decision point with IMIS recommendations. Once the fault is determined, IMIS will reveal how the problem should be solved with the fewest number of steps. This feedback provides instructors and students with performance measures.

If students are not working with an aircraft or flatboard simulator, there is no way to get *results* from a test or component replacement. If the *faulty* component has been randomly selected by IMIS or programmed by an instructor, COACH will provide results of a test. In this case, COACH can present a dialog box telling students what test values should be. The prototype COACH software demonstrates this function in the craftsman level. When IMIS asks students to enter the result of a resistance test across two pins in the Right Forward Multiplexer Matrix, a COACH dialog box appears telling the student what the results are. In this way, COACH can work equally well with or without actual equipment.

The 137 COACH screens depicted in this appendix provide the reader with a simple way of experiencing the COACH application without the software. Each screen and its caption demonstrate the features of COACH. Features which could be implemented to produce training with IMIS.

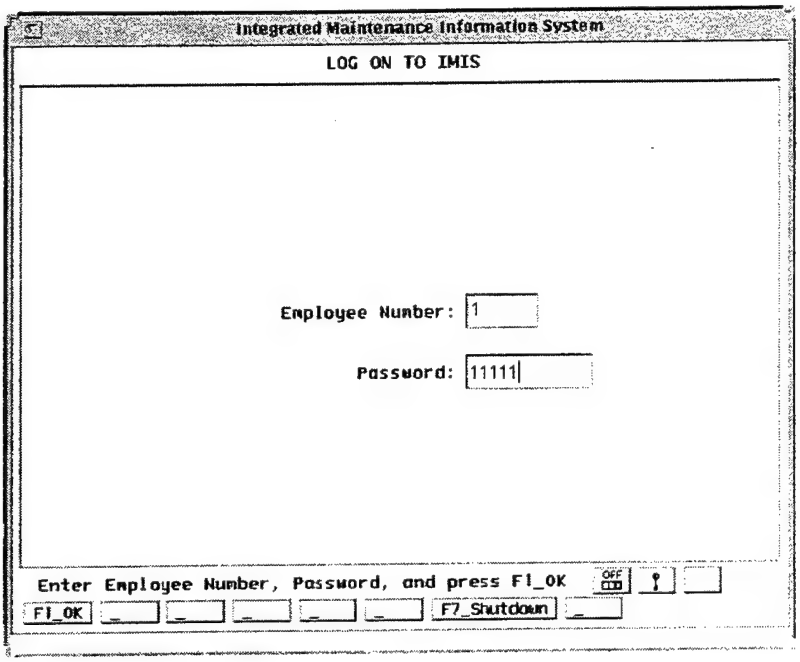

Fig. 1. IMIS sessions begin when a maintainer logs in to the system.

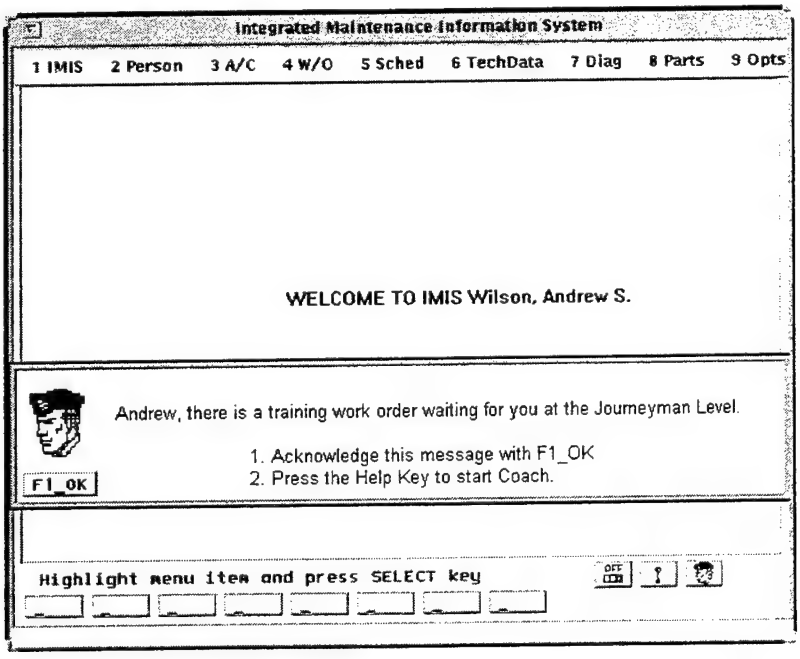

Fig. 2. The COACH intercepts a user login to state that a training scenario has been scheduled at the Journeyman level.

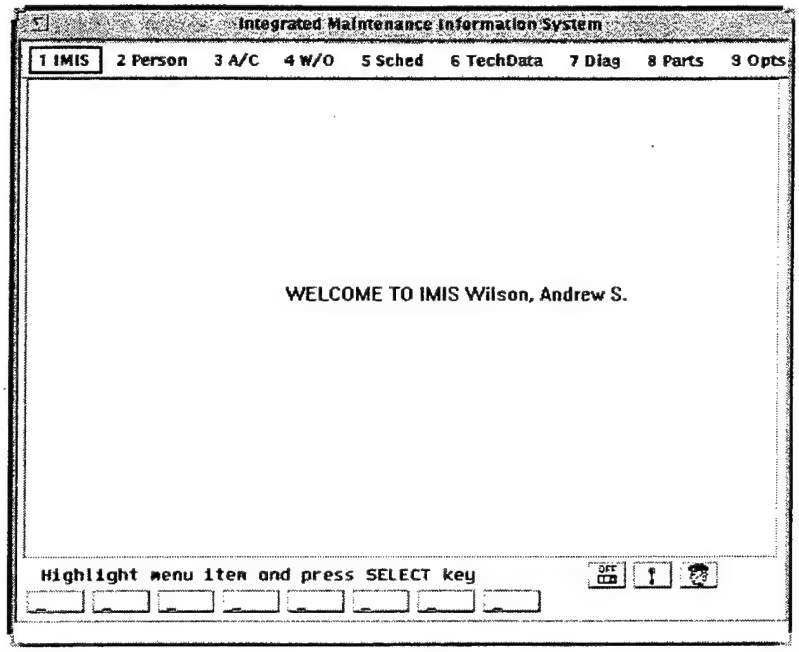

Fig 3. IMIS Main Menu Screen. Notice the small COACH icon in the lower right corner.

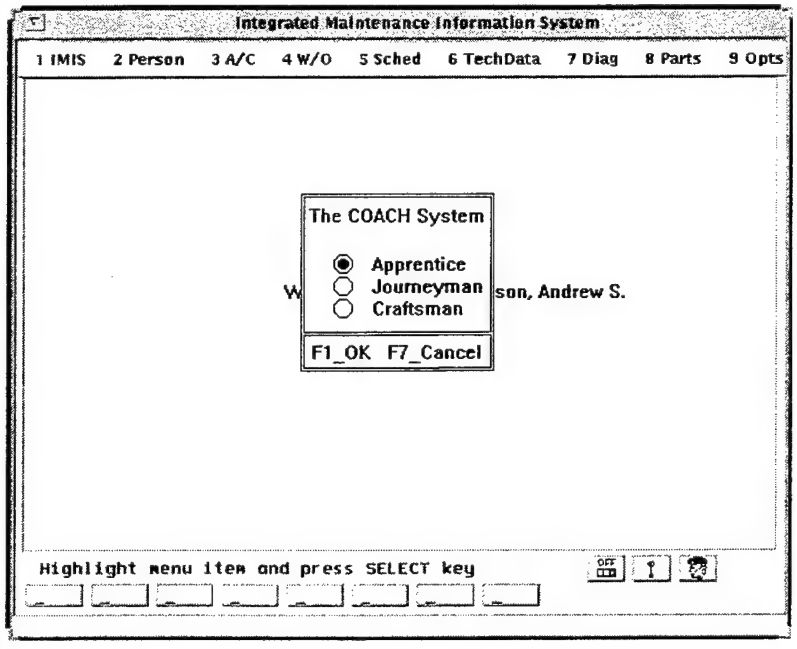

Fig 4. The "F9" or "Help" key starts the COACH system. Step one is to choose the correct COACH level— Apprentice, Journeyman, or Craftsman.

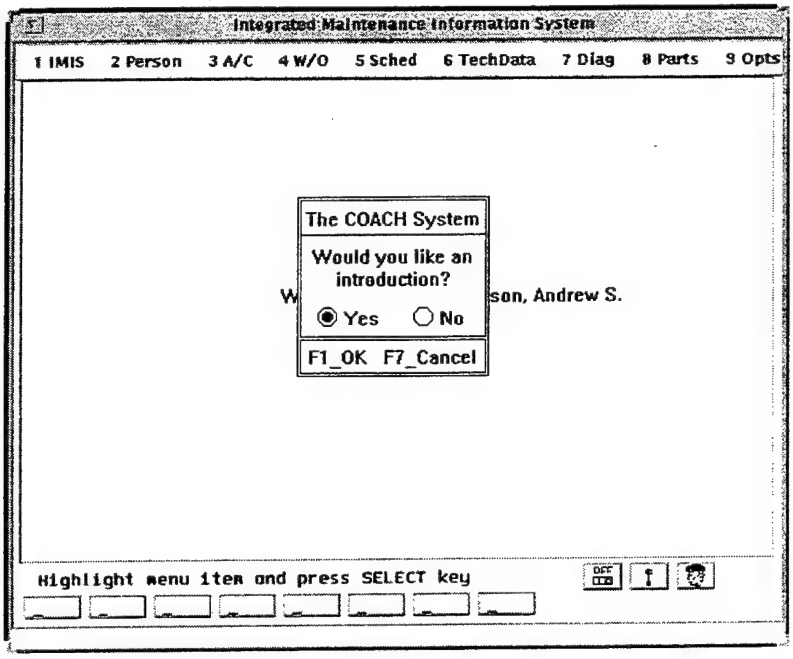

Fig 5. If the Apprentice mode is selected, the COACH offers an introduction.

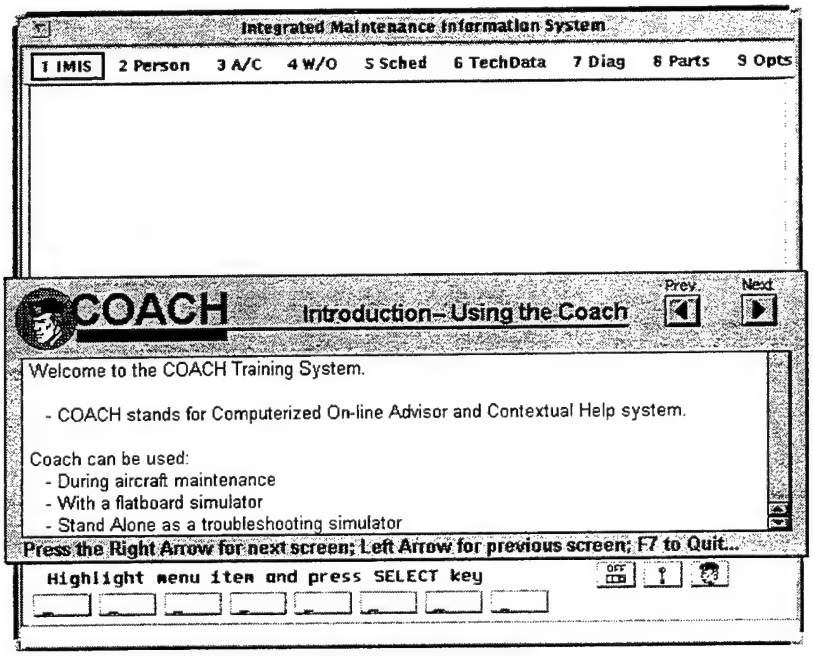

Fig. 6. This is the first screen of the COACH introductory lesson.

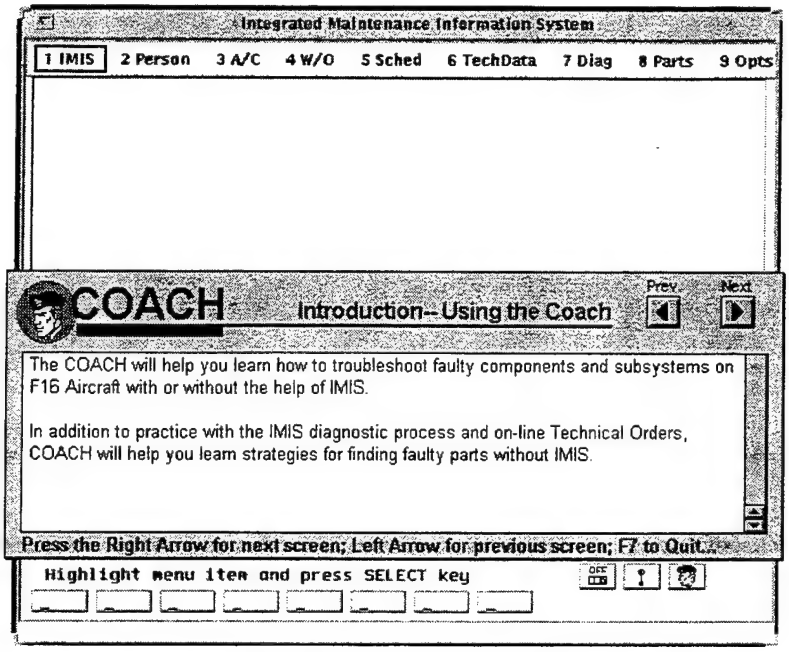

Fig. 7. Introduction screen 2.

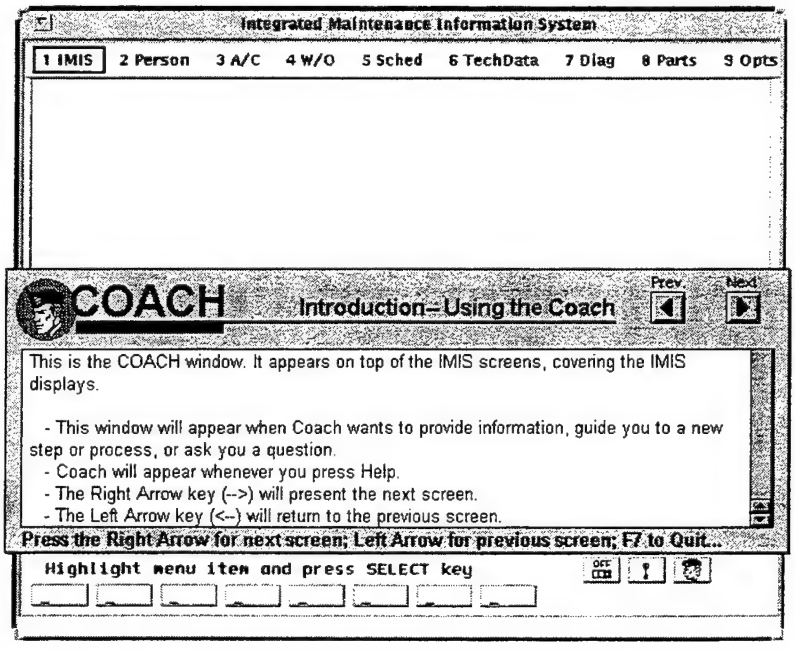

Fig. 8. The Introduction lesson orients the user to COACH controls.

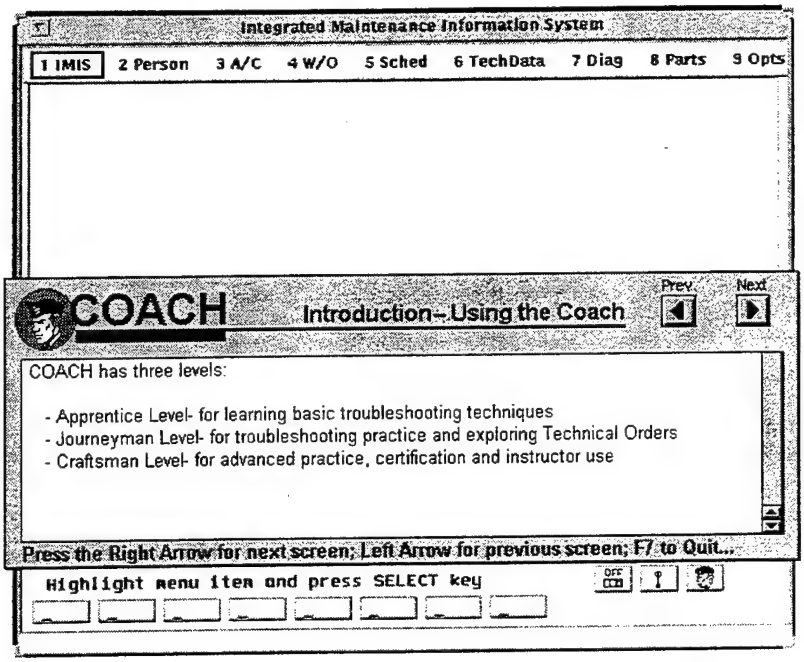

Fig. 9. The Introduction explains the levels of the COACH tutor.

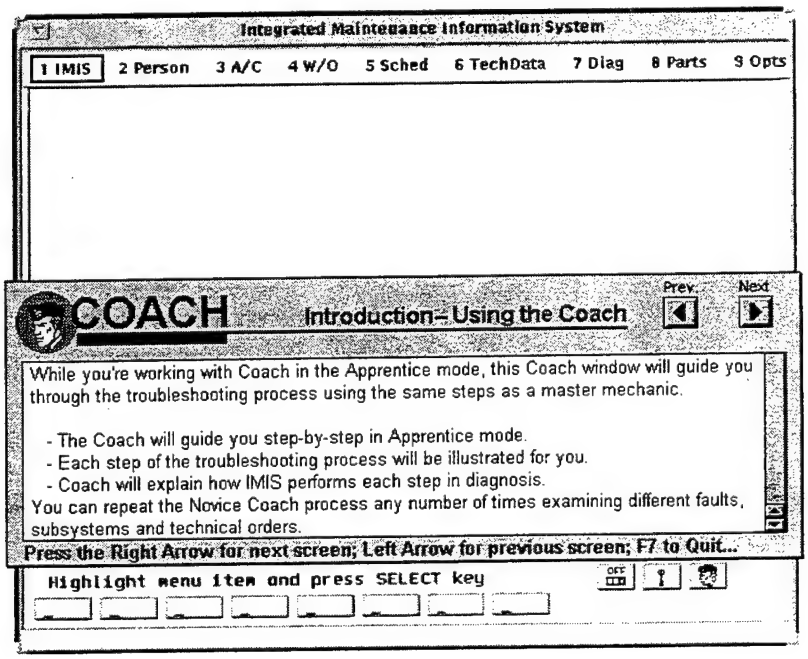

Fig. 10. An explanation of the Apprentice level of COACH training.

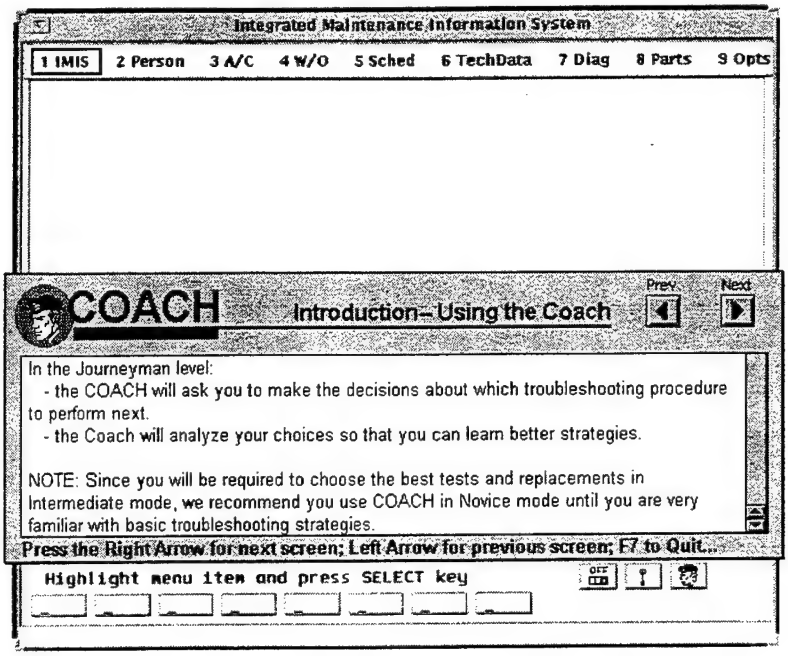

Fig. 11. An explanation of the Journey man level of COACH training.

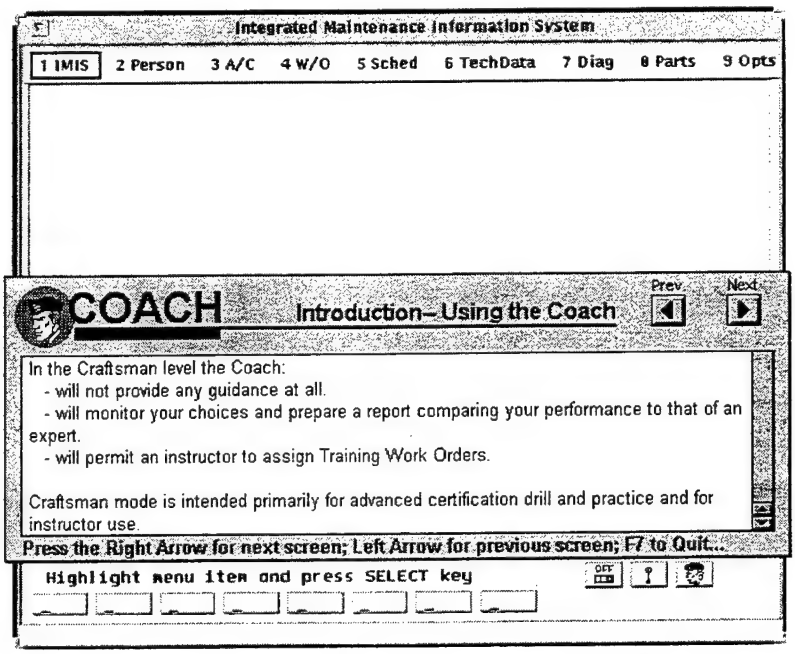

Fig. 12. An explanation of the Craftsman level of COACH training.

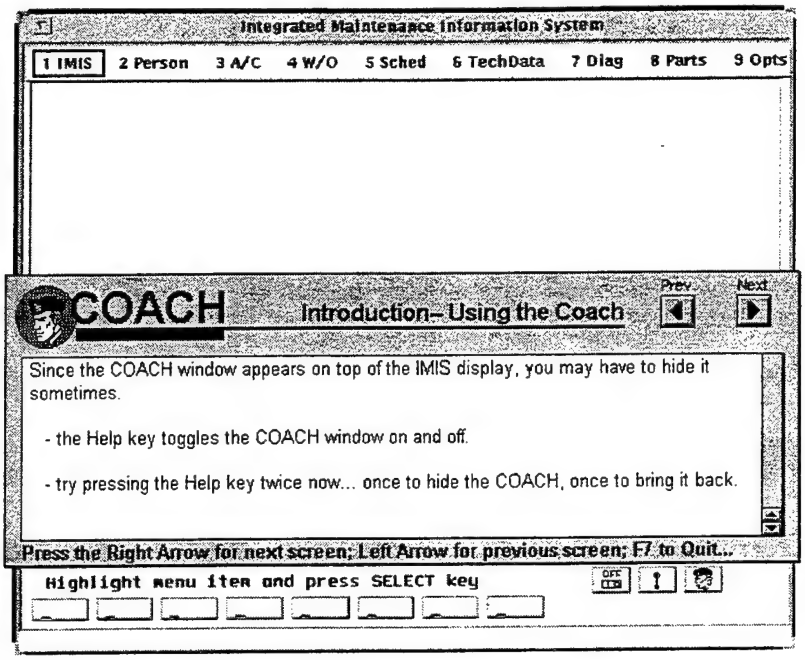

Fig. 13. The Intro teaches how to toggle the COACH window on and off.

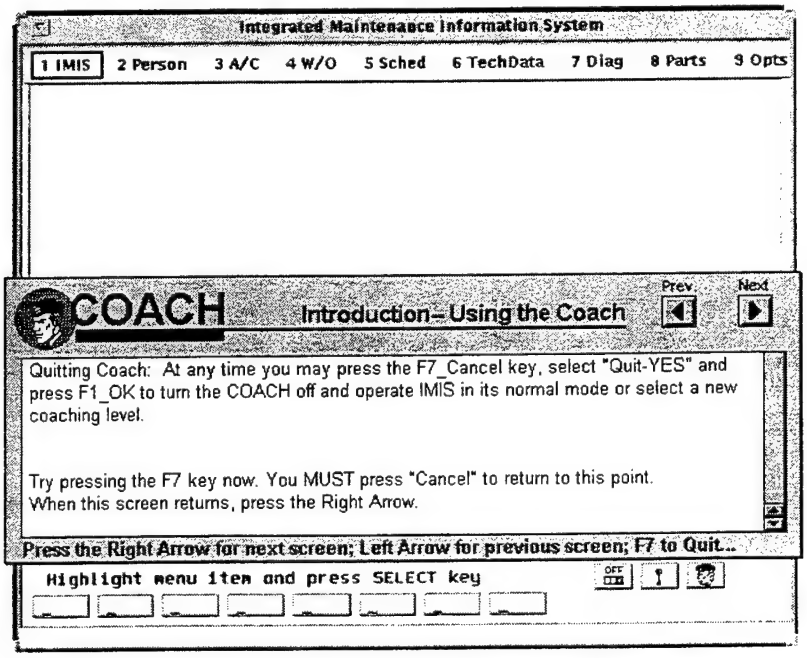

Fig. 14. The Intro teaches how to quit the COACH.

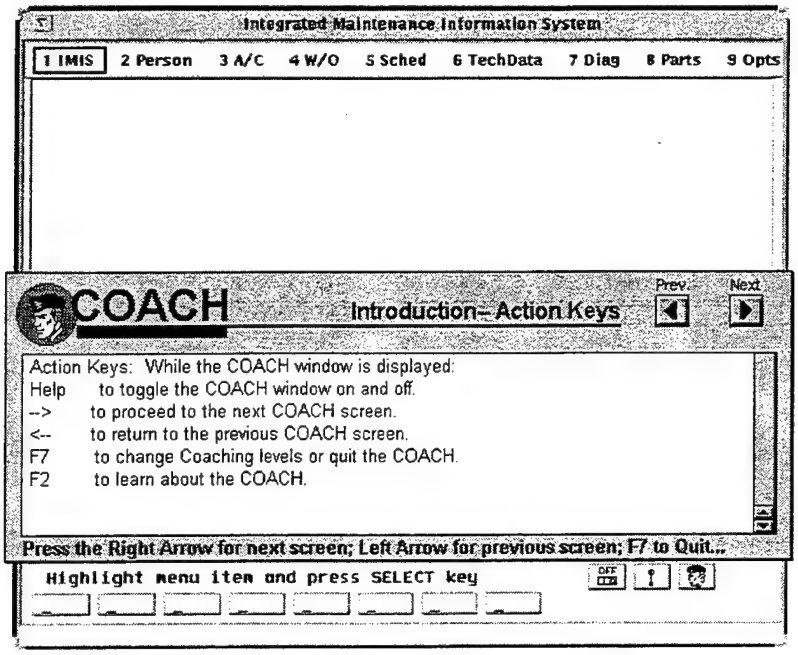

Fig. 15. The Introduction presents a summary of the COACH action keys.

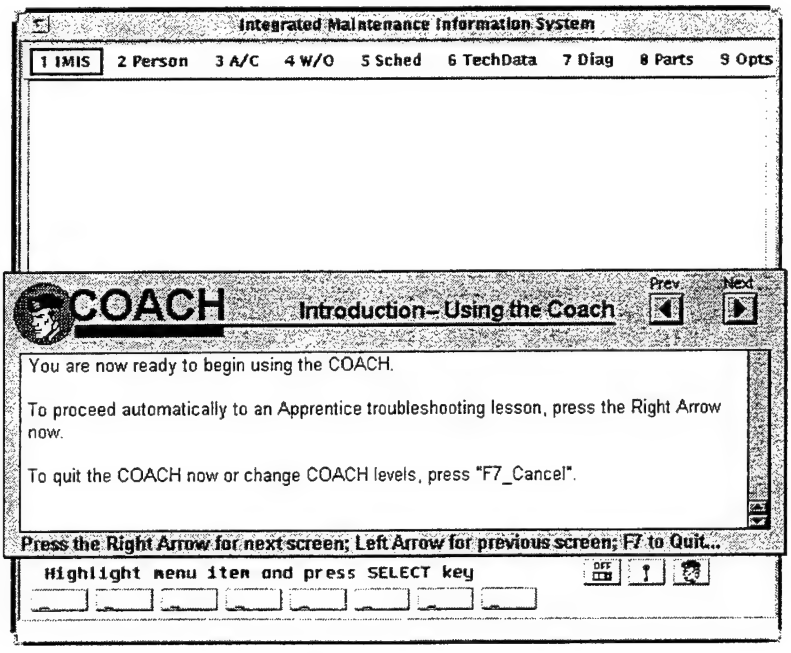

Fig. 16. The last screen in the COACH Introduction lesson.

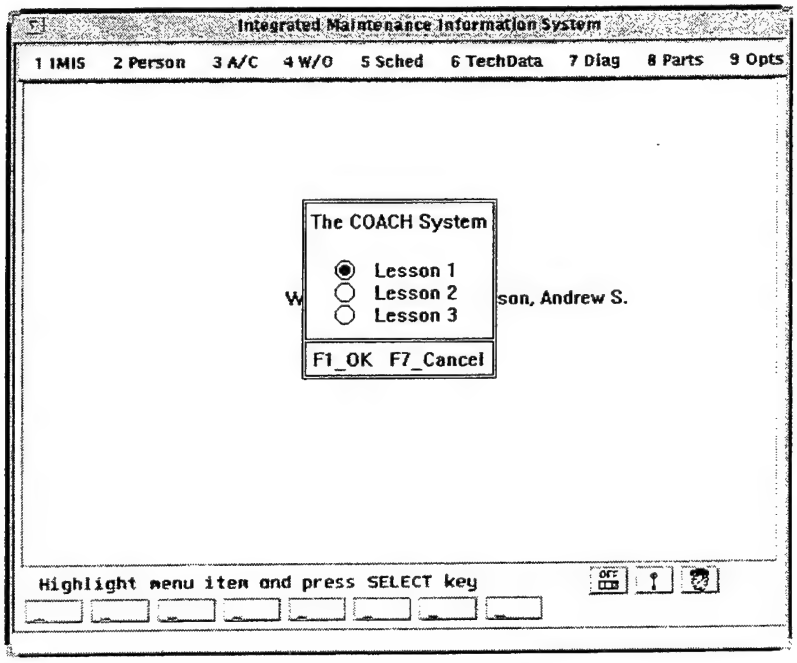

Fig. 17. This screen is used to select lessons One, Two or Three at the Apprentice level.

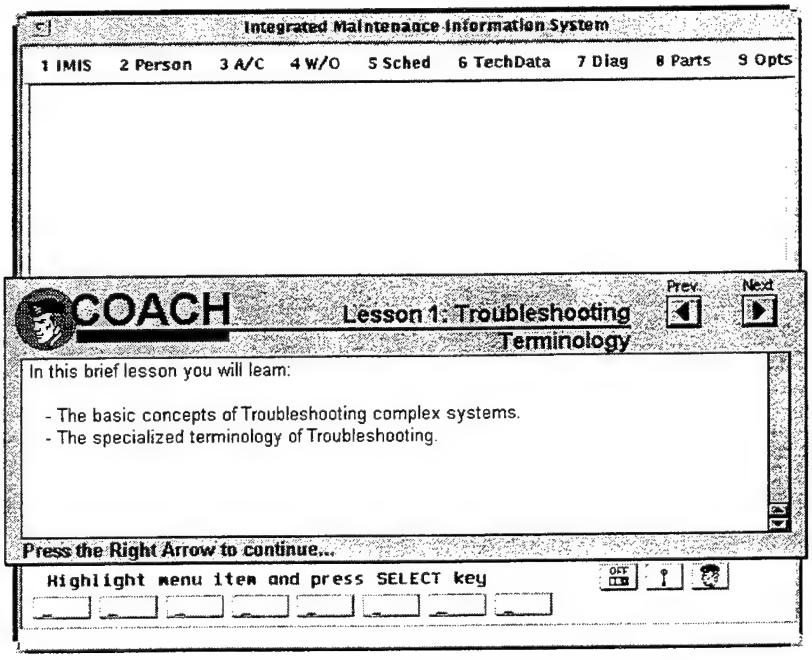

Fig. 18. This is the first screen in the Apprentice mode Lesson One on troubleshooting terminology.

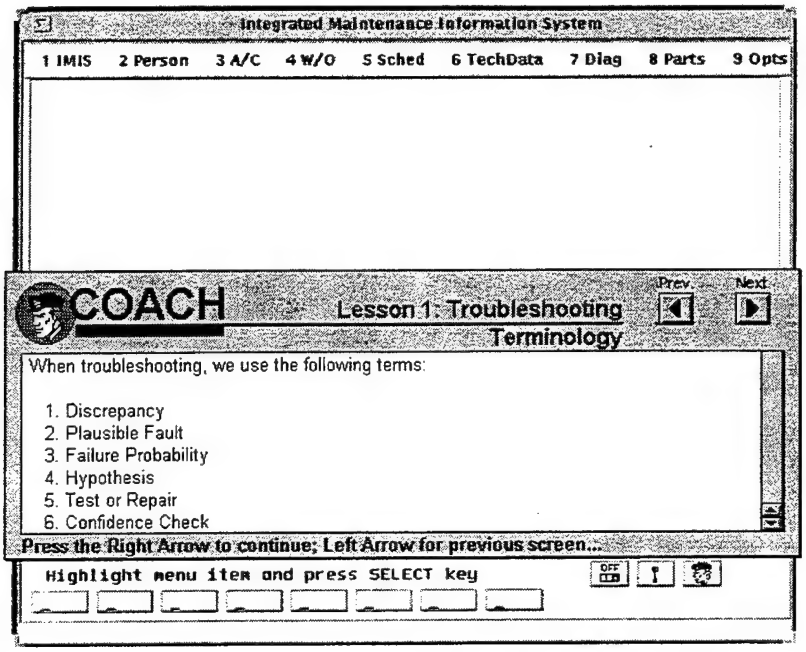

Fig 19. Lesson One introduces specialized troubleshooting terminology.

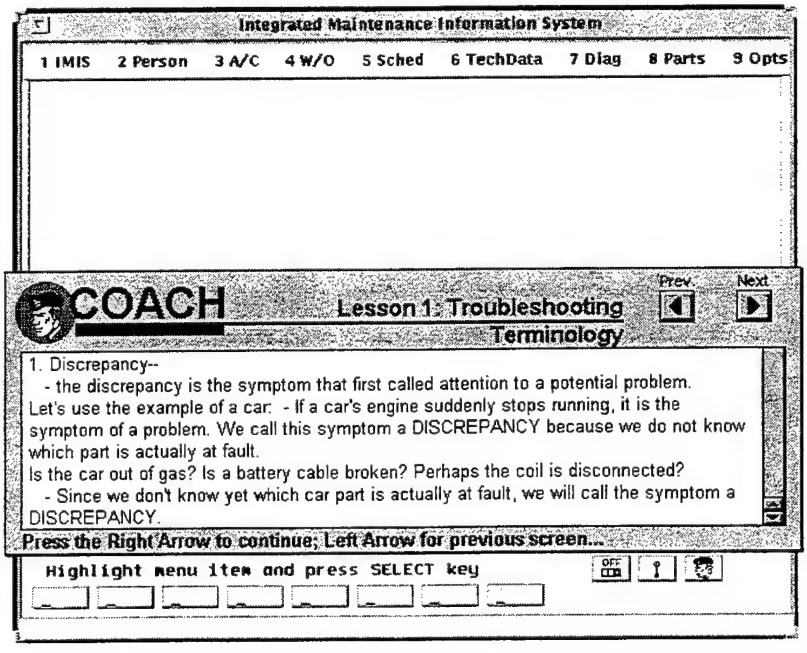

Fig. 20. Each troubleshooting term is carefully explained.

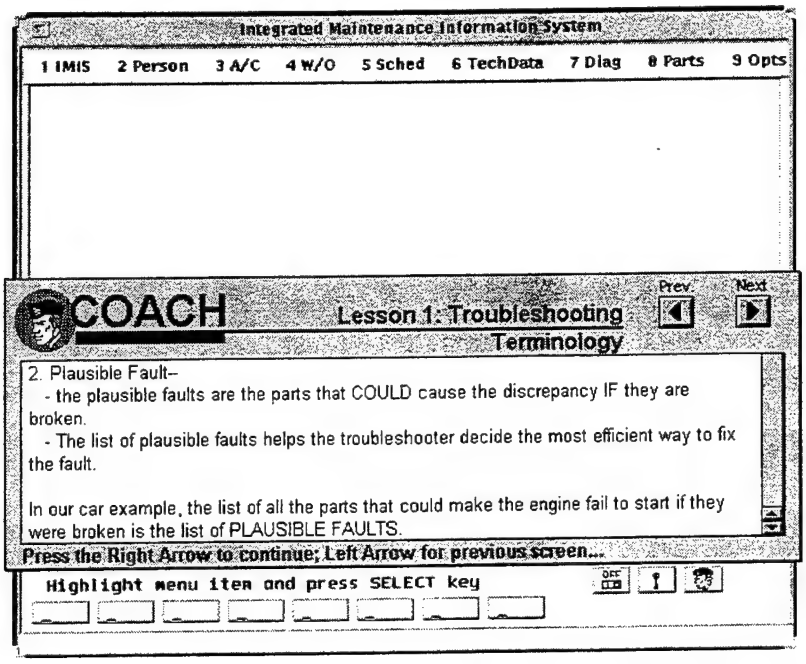

Fig. 21. Troubleshooting terms are related to a familar kind of ignition problem with a generic automobile.

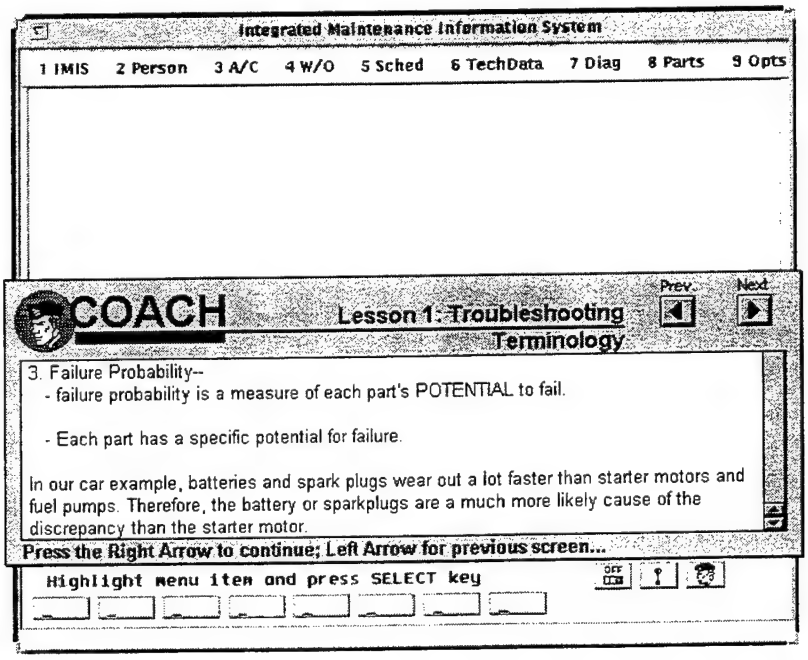

Fig. 22. Failure probability is a key piece of information used by IMIS for test selection. Since it is stored in the CDM, it could be provided by IMIS as data to aid human troubleshooters.

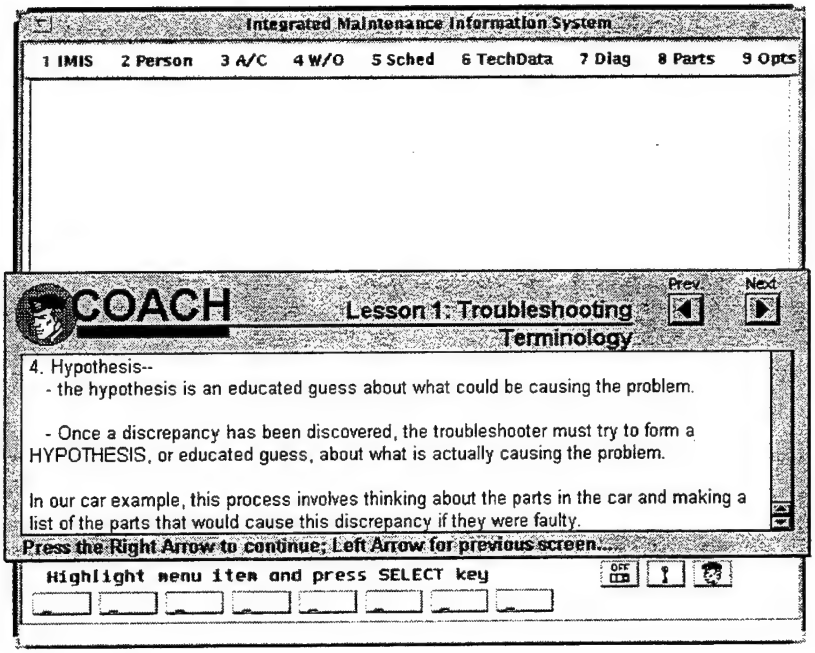

Fig. 23. Introduction of the term "hypothesis."

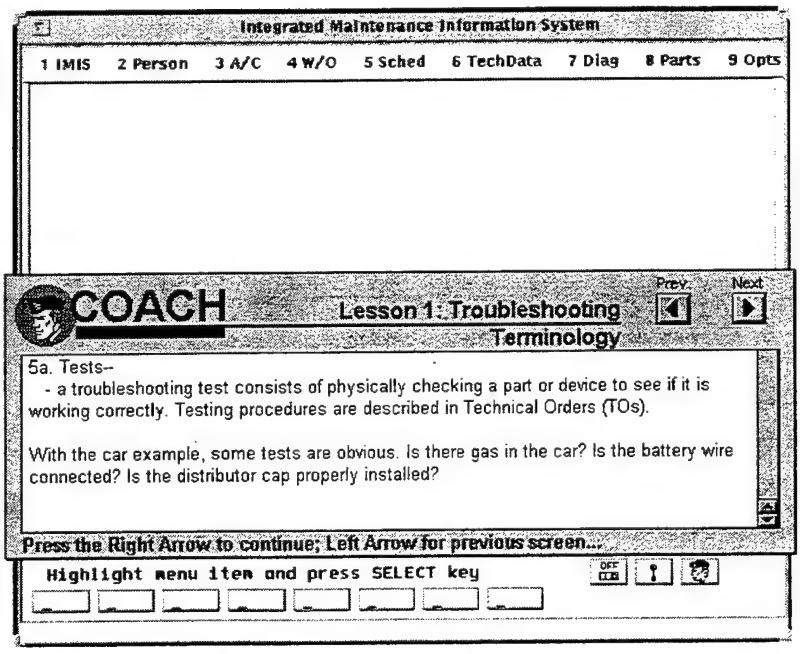

Fig. 24. Tests and repairs are considered independently.

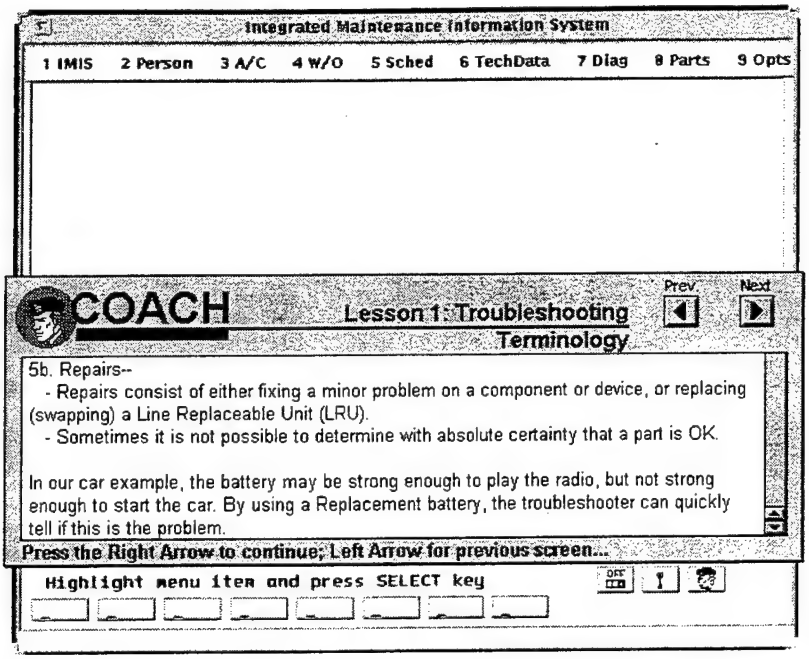

Fig. 25. COACH introduces repair or replacement as a troubleshooting strategy.

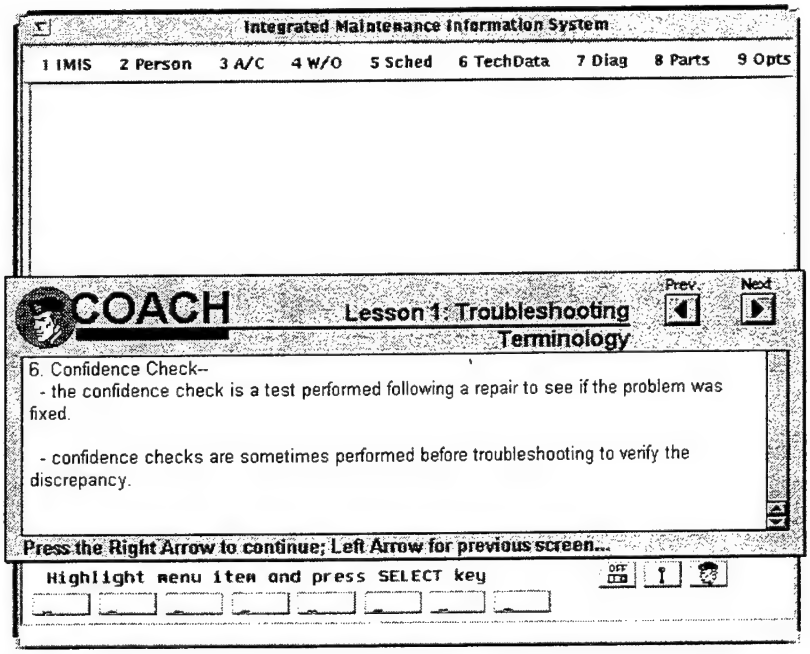

Fig. 26. The Confidence check.

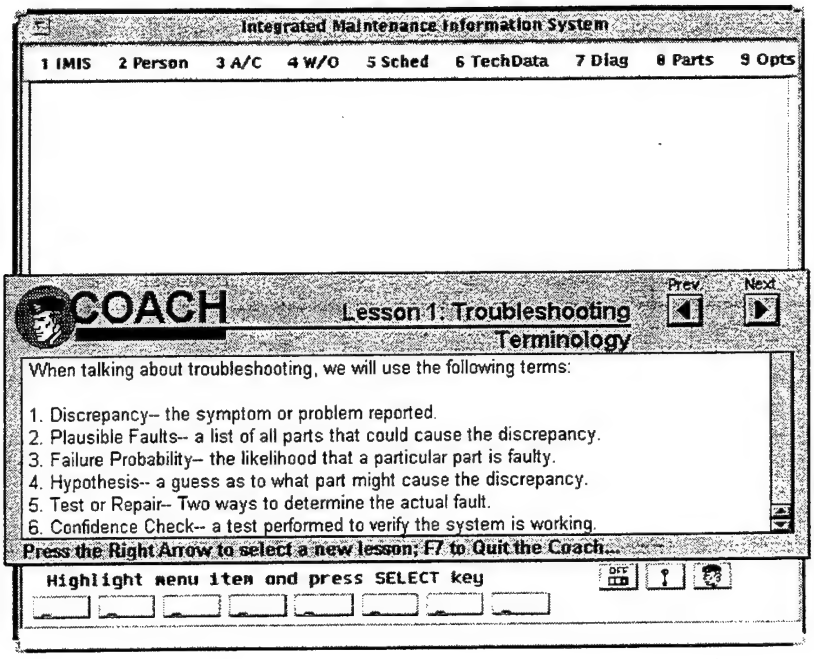

Fig. 27. Apprentice Lesson One conclusion.

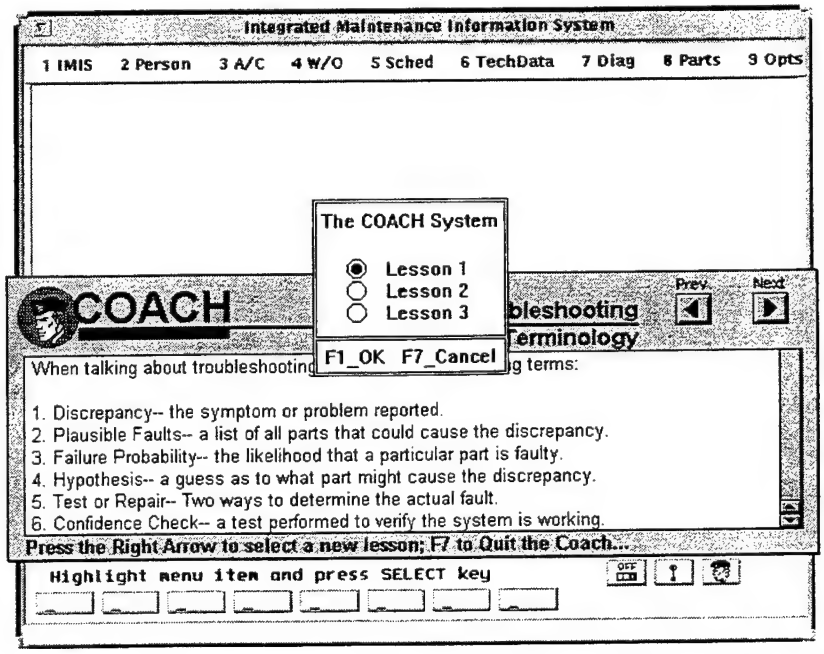

Fig. 28. When the end of lesson one is reached, the COACH automatically offers more lessons.

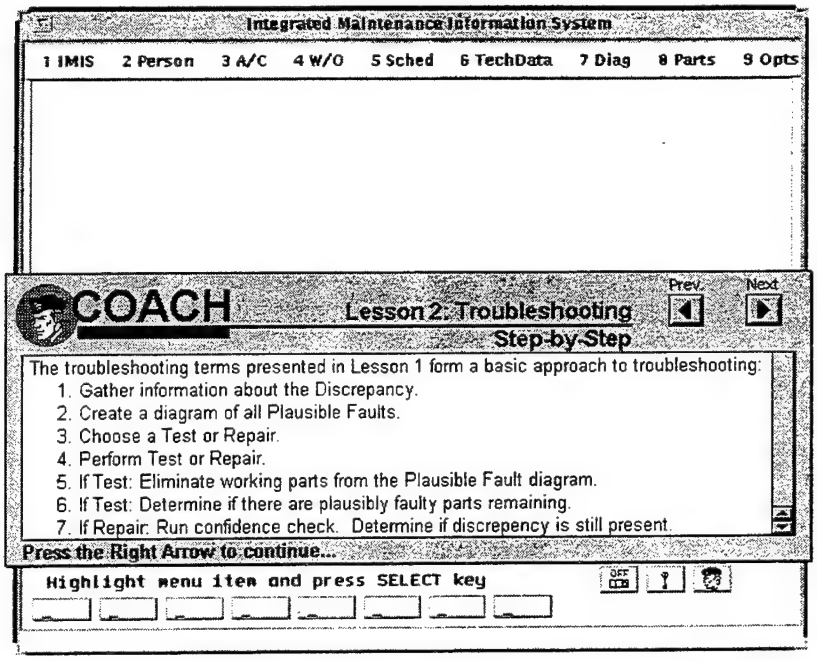

Fig. 29. Lesson Two presents a step-by-step troubleshooting model.

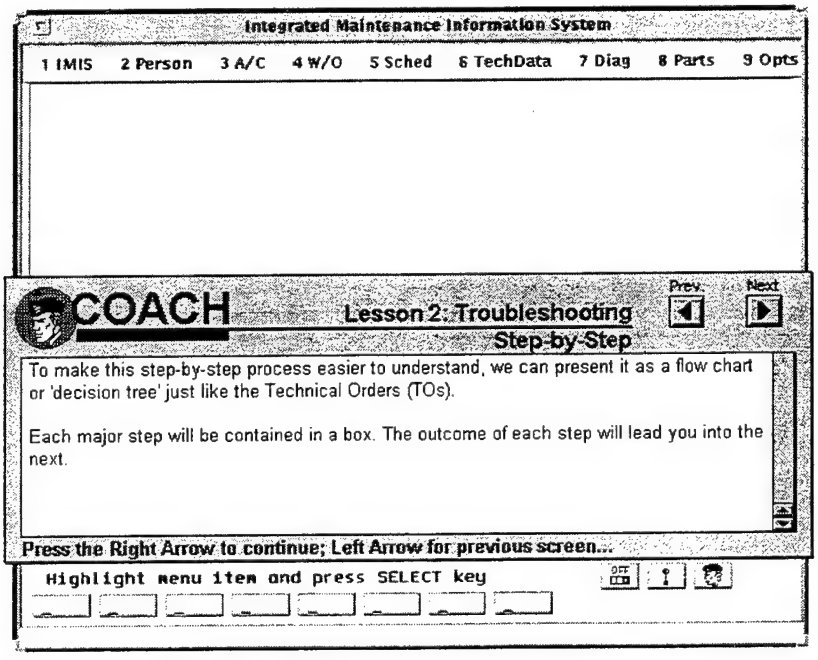

Fig. 30. The troubleshooting strategy is explained one component at a time for clarity.

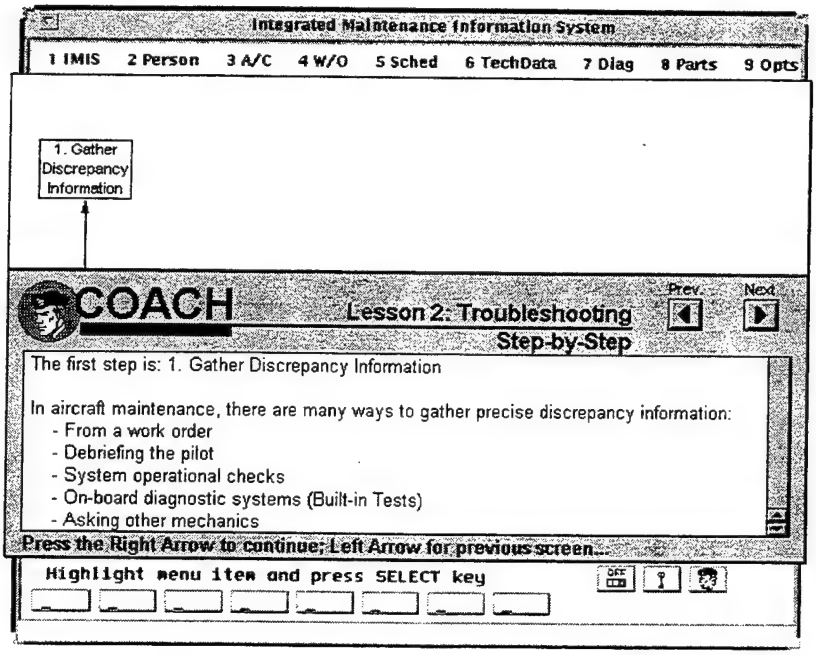

Fig. 31. Troubleshooting model step one.

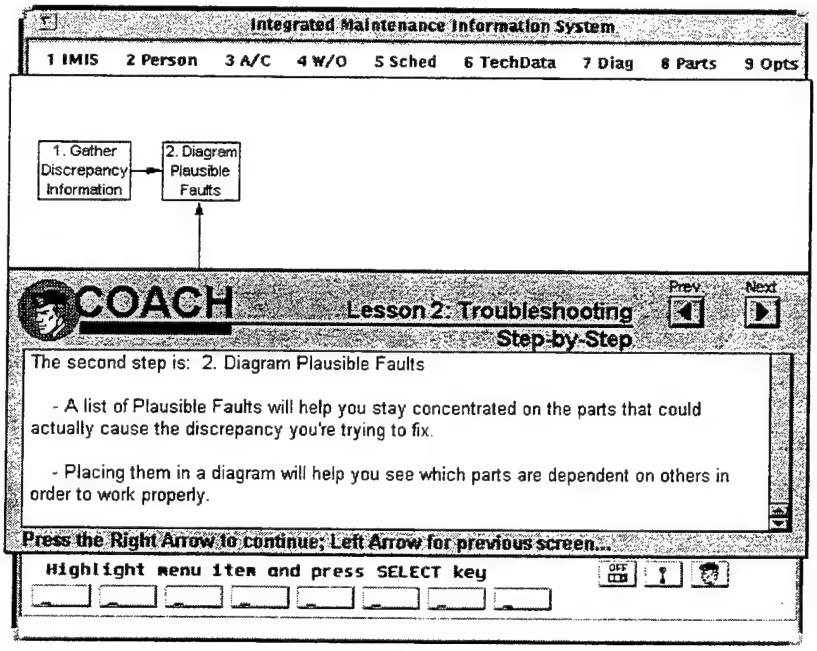

Fig. 32. Troubleshooting model step two.

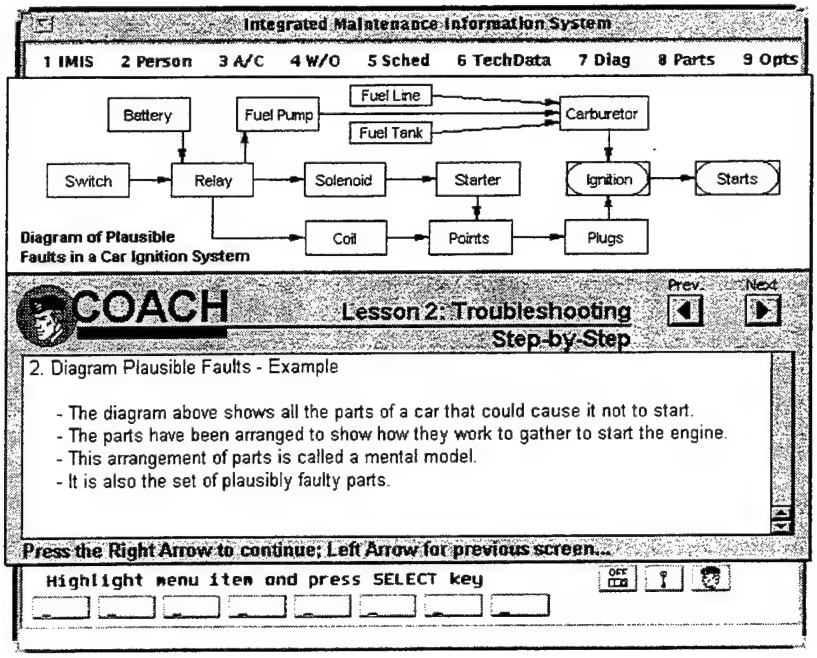

Fig. 33. Specific steps are explained with graphics in the amplification area above the COACH window.

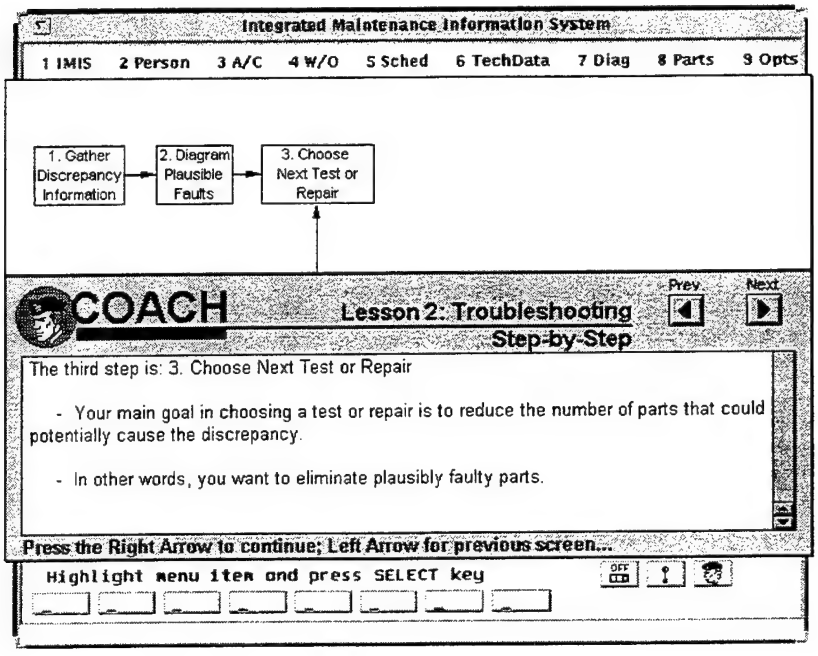

Fig. 34. Troubleshooting strategy step three.

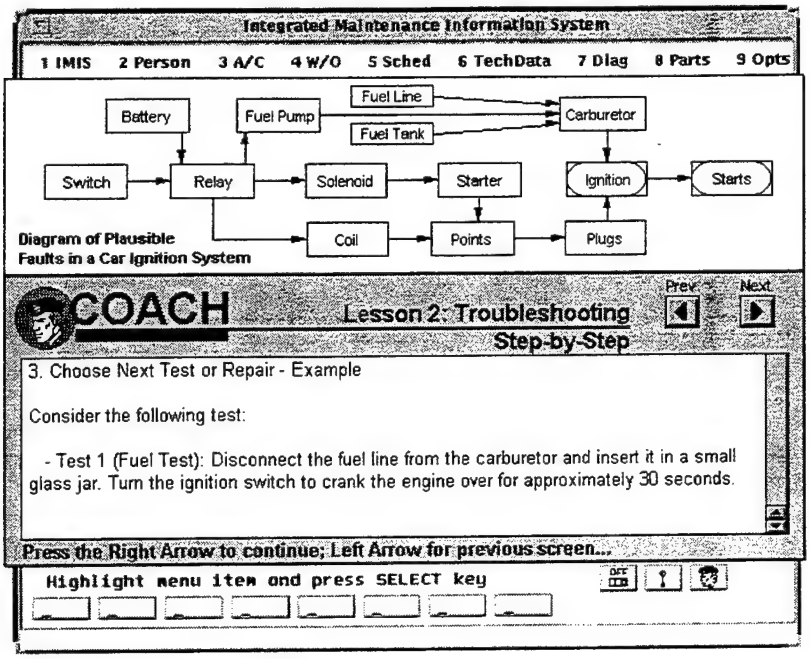

Fig. 35. Explanations in Lesson Two use the familiar example of a car ignition system.

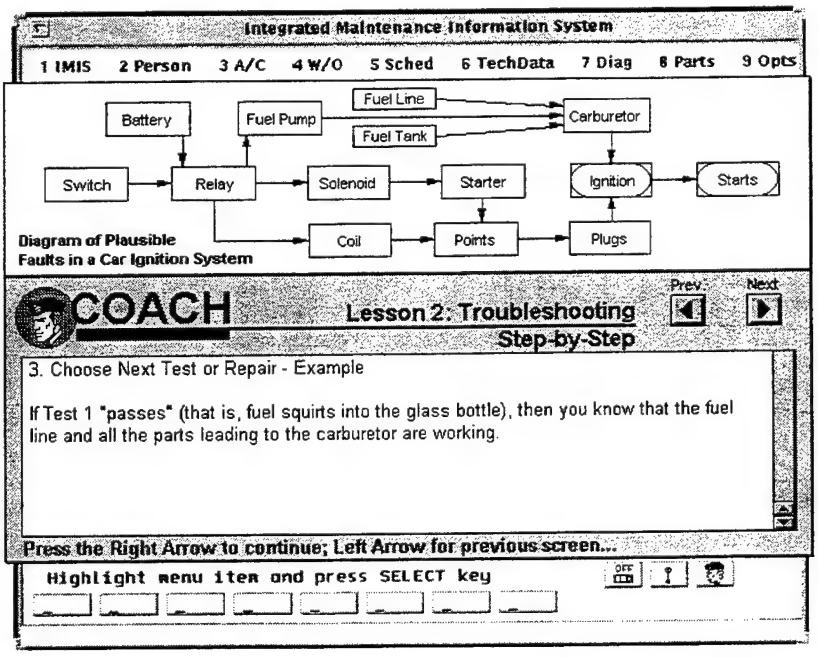

Fig. 36. The auto example makes it easy to understand the purpose of different tests.

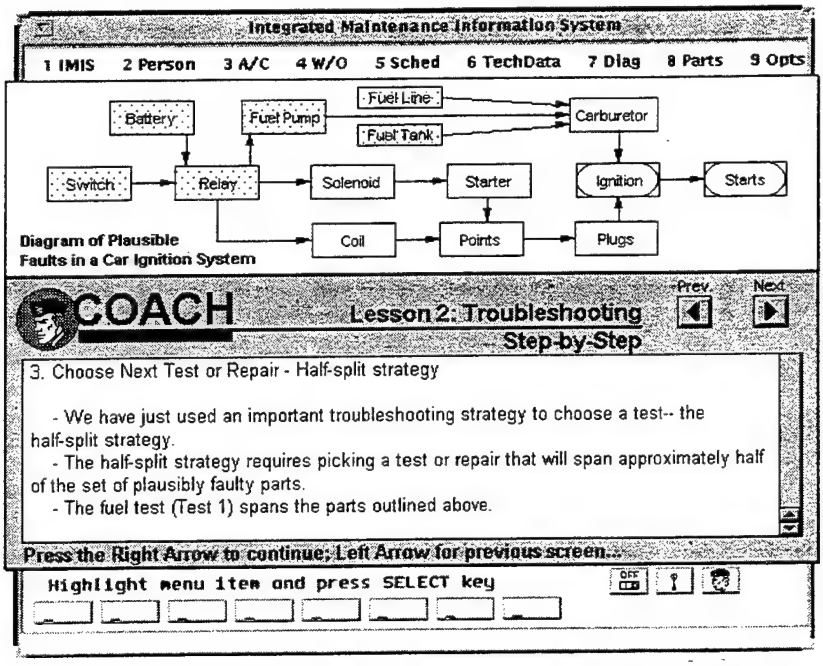

Fig. 37. Notice the eliminated parts in the amplification window.

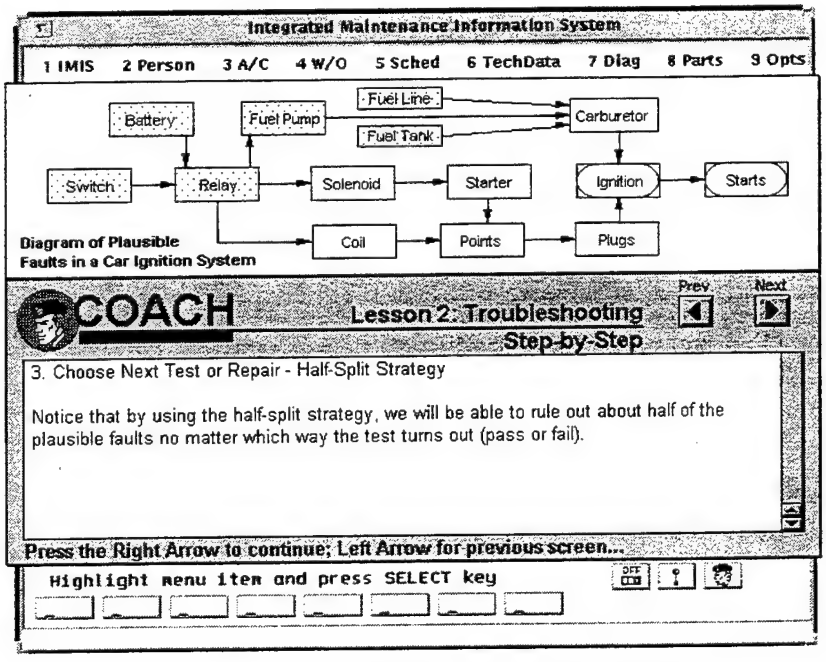

Fig. 38. The COACH streesses the half-split strategy.

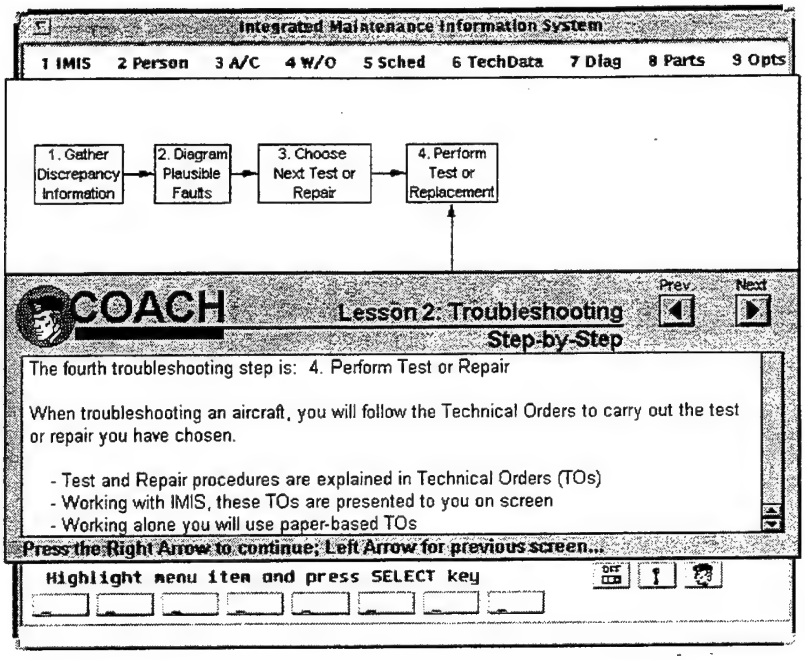

Fig. 39. Troubleshooting step four.

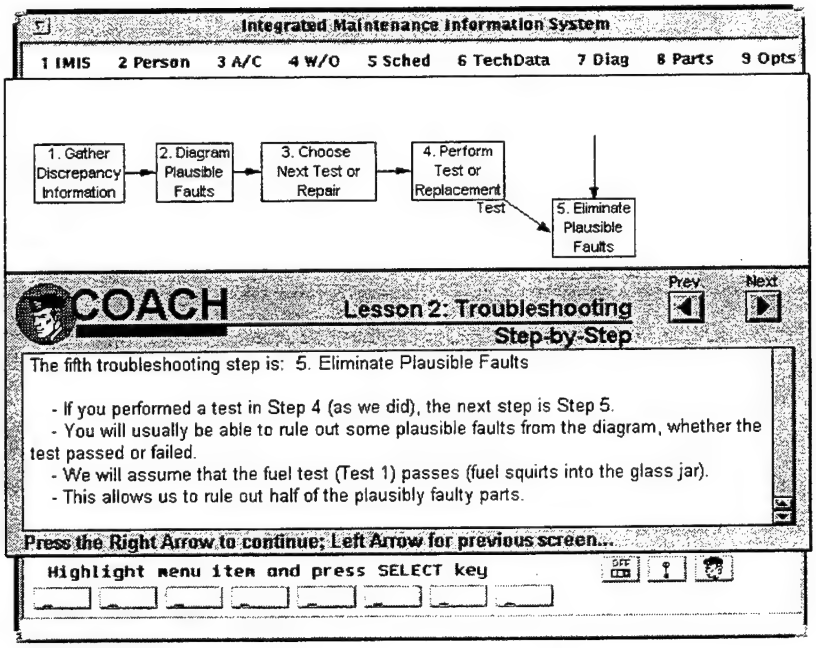

Fig. 40. Troubleshooting step five.

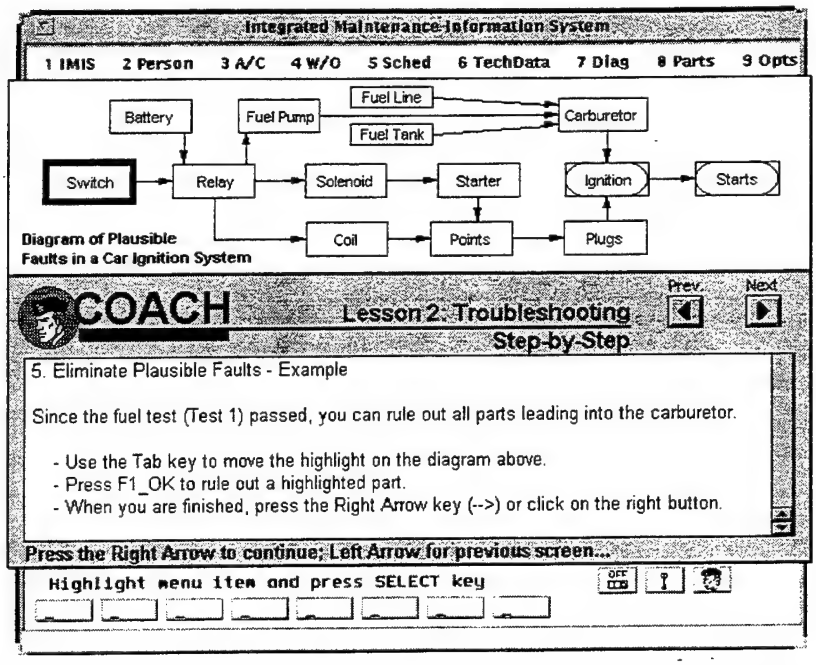

Fig. 41. This simple interaction asks the student to eliminate parts cleared by this test.

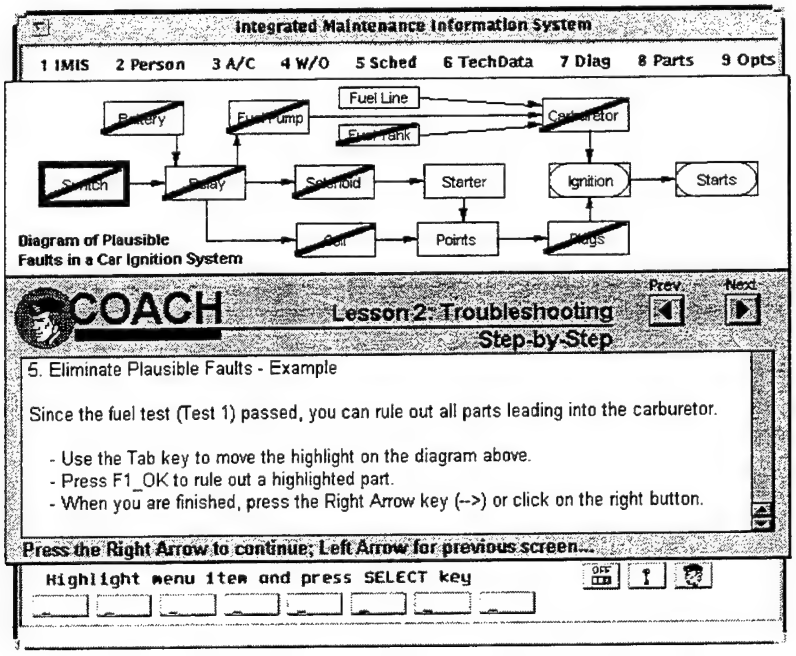

Fig. 42. The student has chosen to eliminate the parts shown with the forward slashes through them.

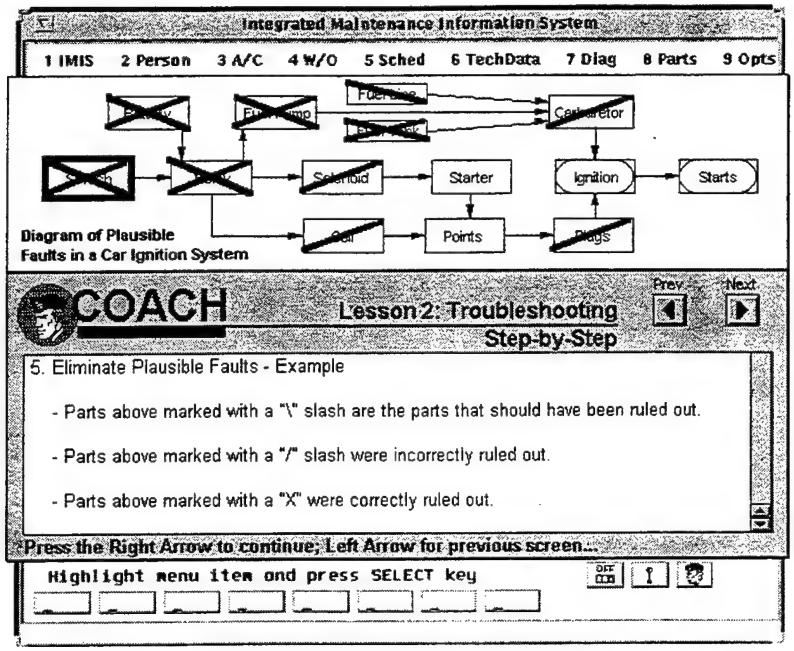

Fig. 43. Basic feedback shows the student what was correctly eliminated, what should have been eliminated, and what should not have been eliminated.

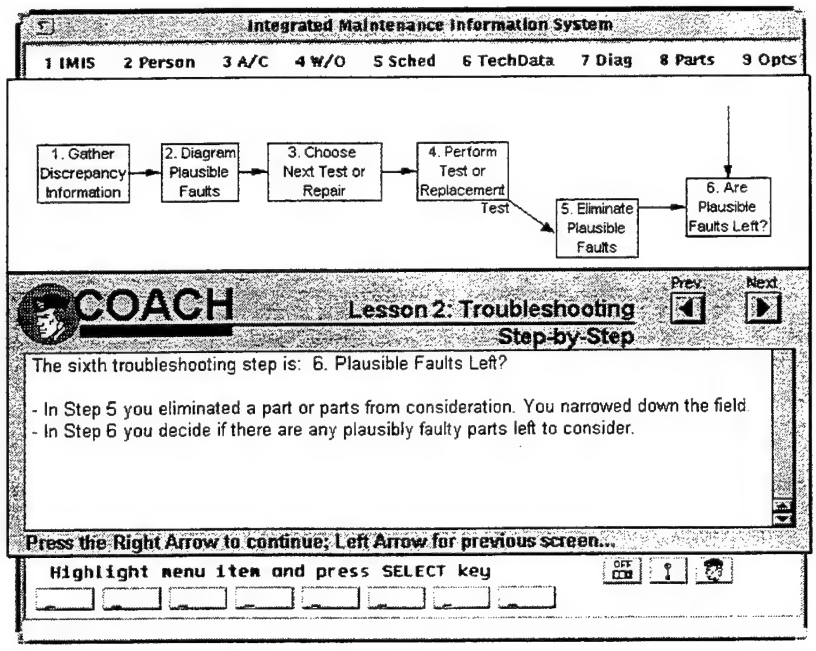

Fig. 44. Troubleshooting step six.

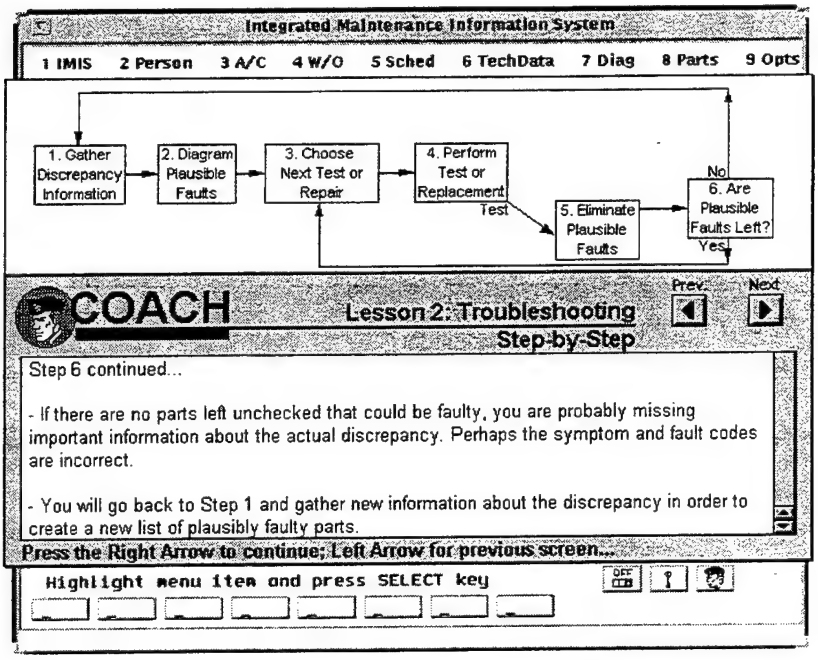

Fig. 45. Different outcomes from step six are shown with arrows.

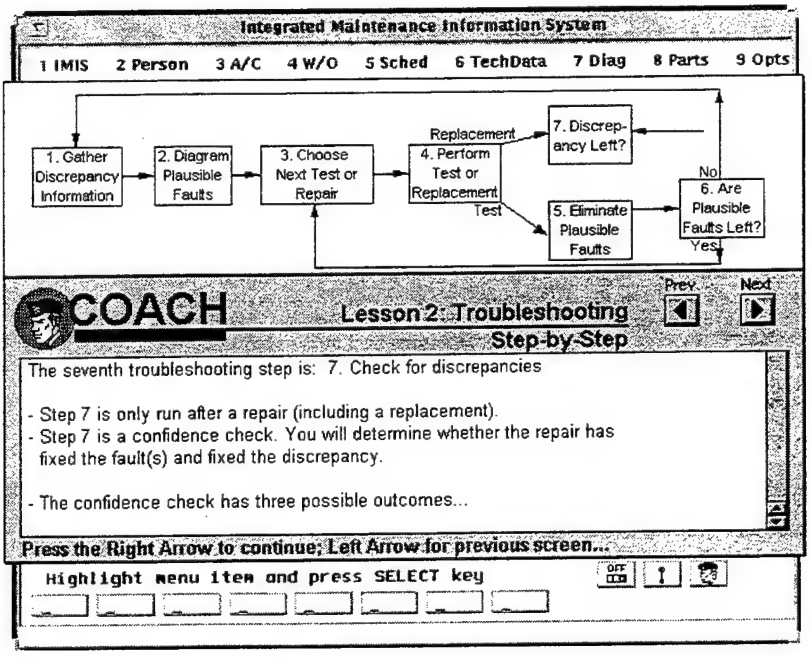

Fig. 46. Troubleshooting step seven is only performed after a replacement or repair.

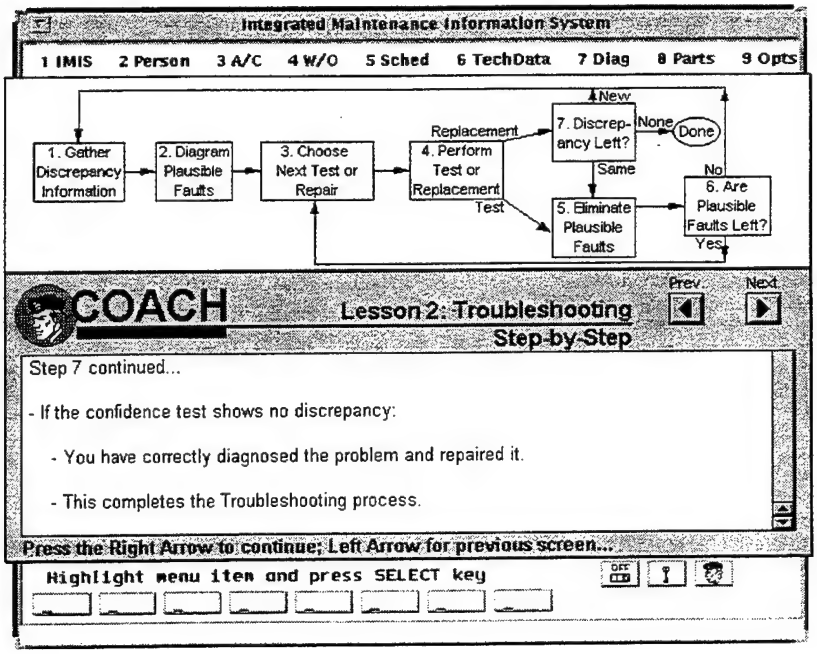

Fig. 47. Troubleshooting step seven has three possible outcomes shown with arrows.

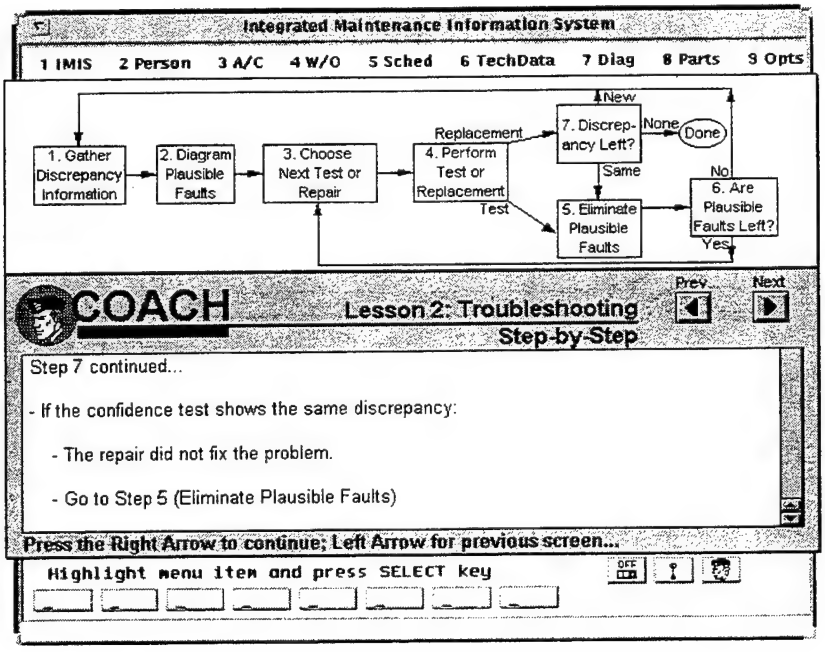

Fig. 48. A successful confidence check signifies a completed repair.

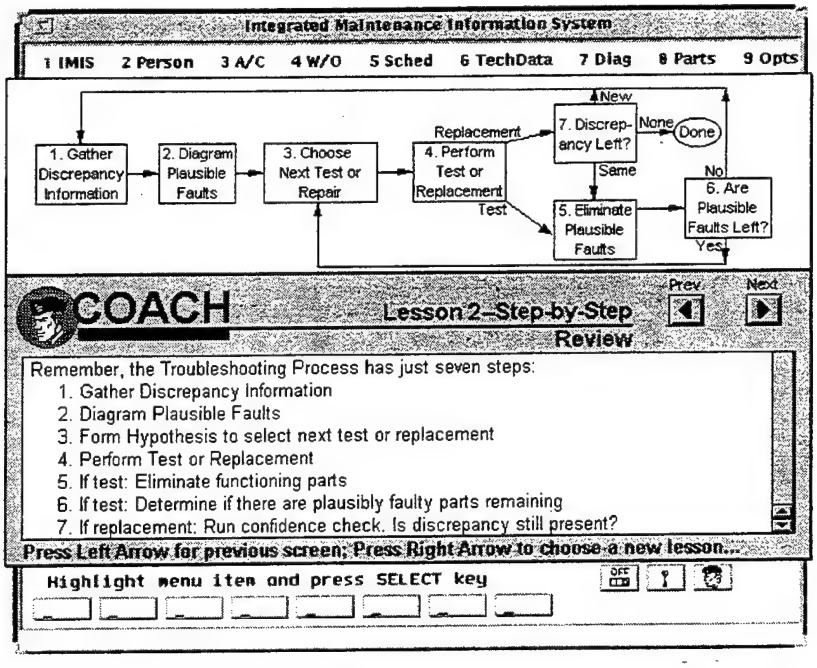

Fig. 49. A simple view of the generic troubleshooting decision tree.

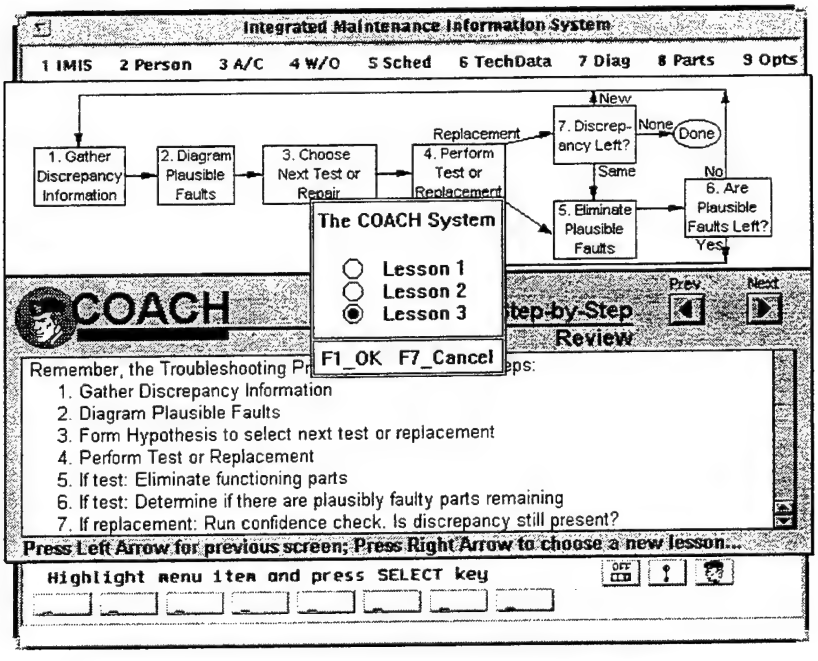

Fig. 50. When the student completes Lesson Two, the next lesson is automatically offered.

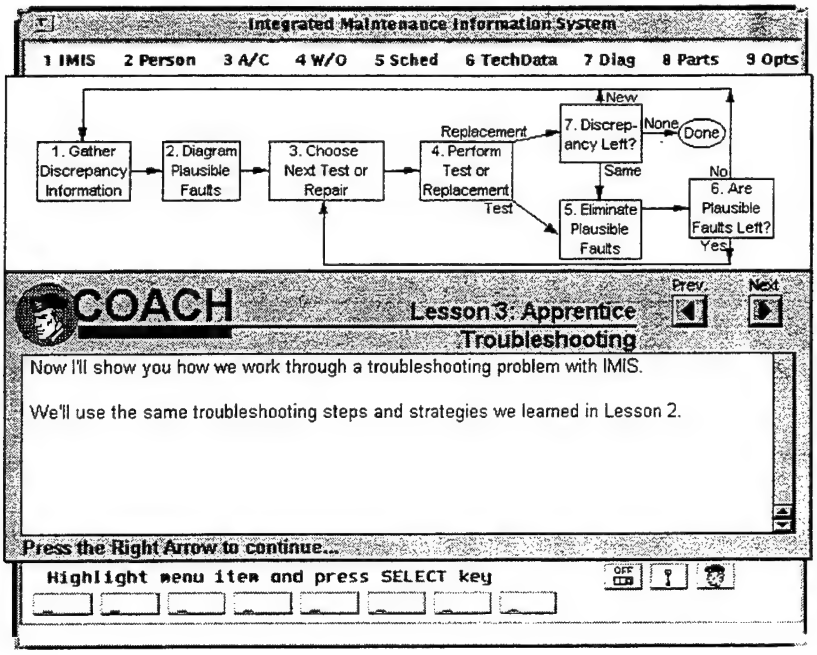

Fig. 51. Apprentice Level Lesson Three is the first repeatable diagnostic scenario.

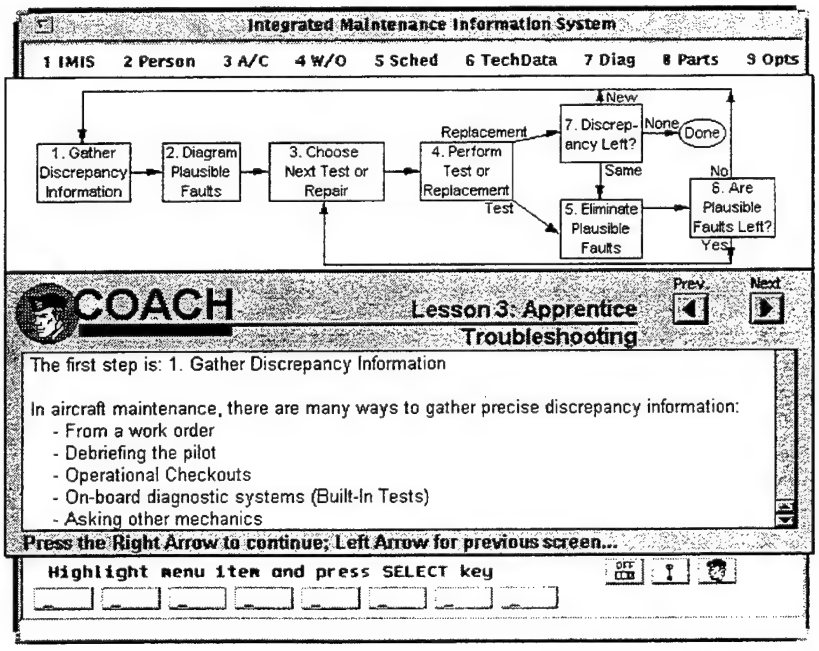

Fig. 52. Lesson Three relates the steps in the seven-part troubleshooting model to the process used for diagnostics by IMIS.

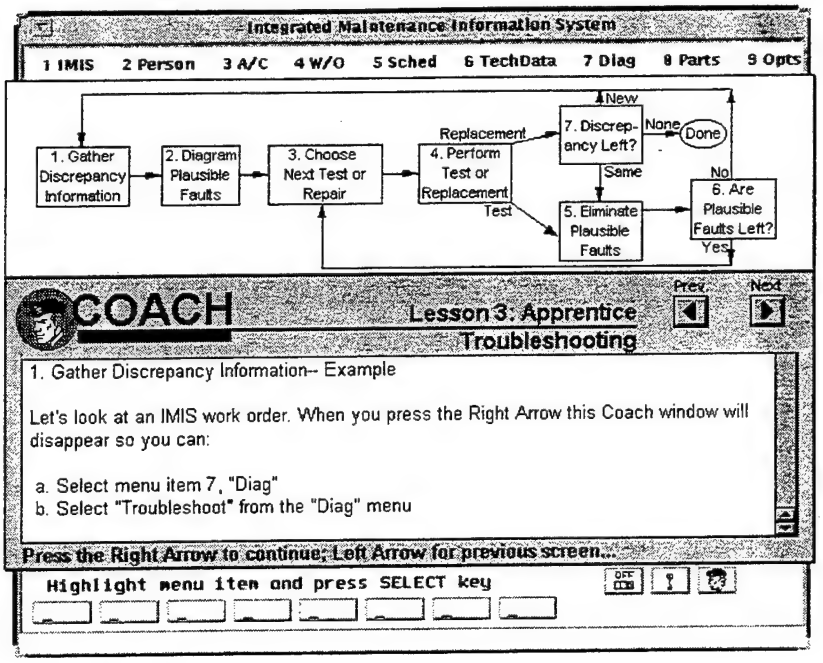

Fig. 53. The COACH provides instructions to the student if the next step isn't obvious.

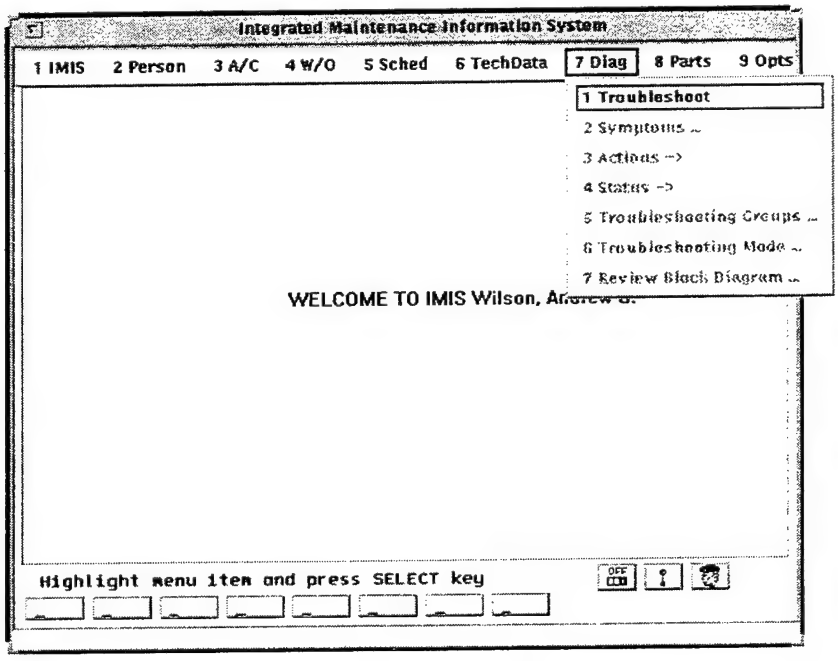

Fig. 54. Diagnostics work is begun with IMIS by selecting "Troubleshoot" from the "Diag" menu.

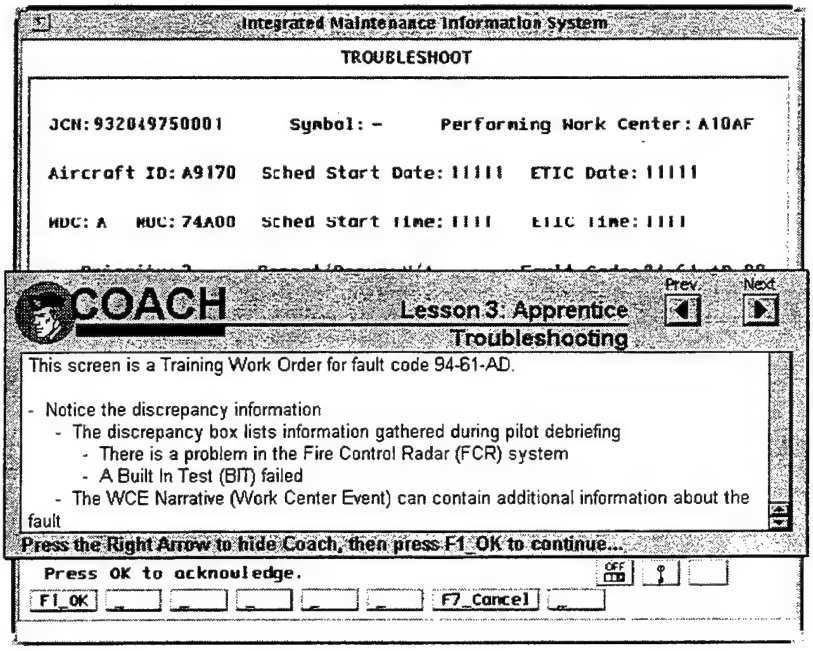

Fig. 55. At the Apprentice level, basic IMIS interactions are explained. This should help reinforce IMIS procedures as well as independent troubleshooting skills.

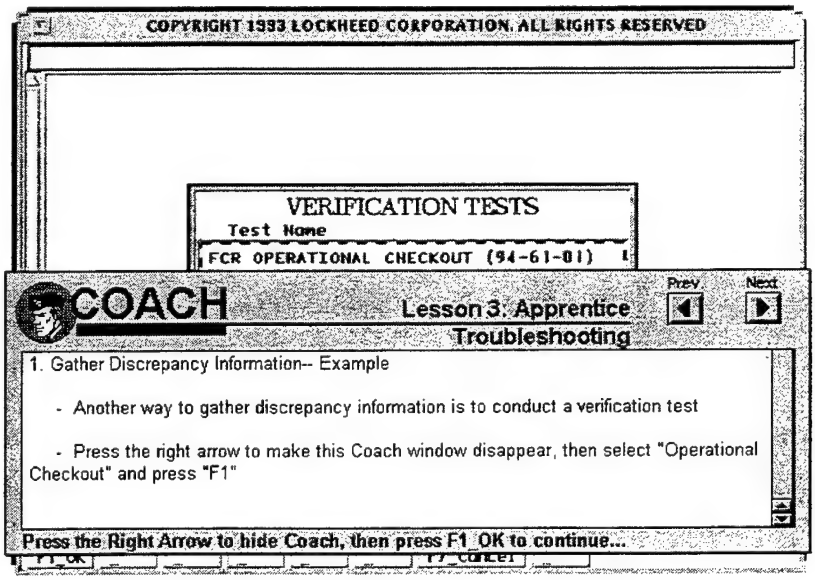

Fig. 56. The COACH shows that IMIS verification tests are another way of gathering discrepancy information.

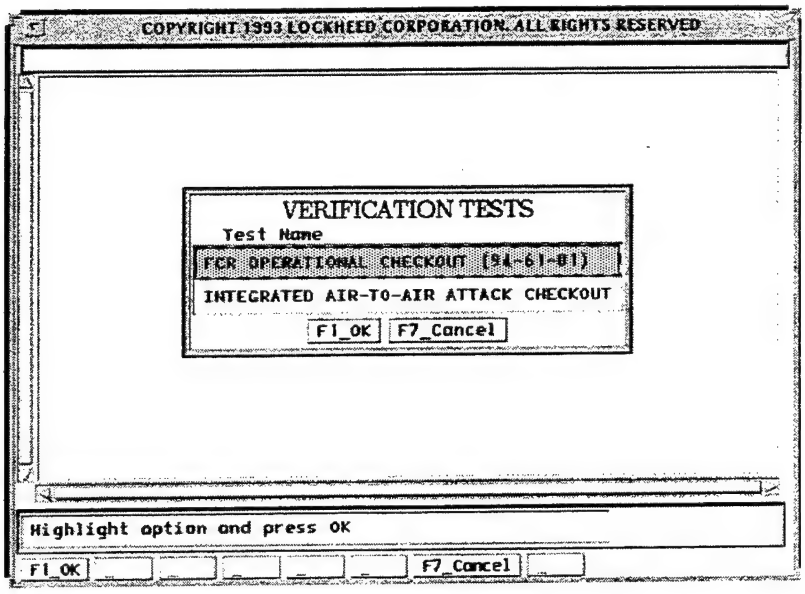

Fig. 57. Beginning an IMIS verification test.

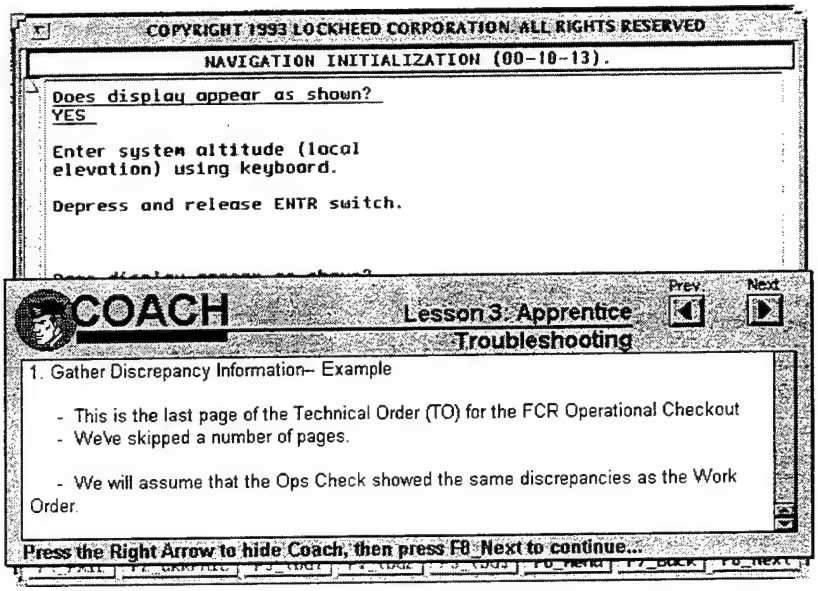

Fig. 58. In the stand alone training mode without extra equipment, COACH can shorten nonessential TO's to keep the training session moving.

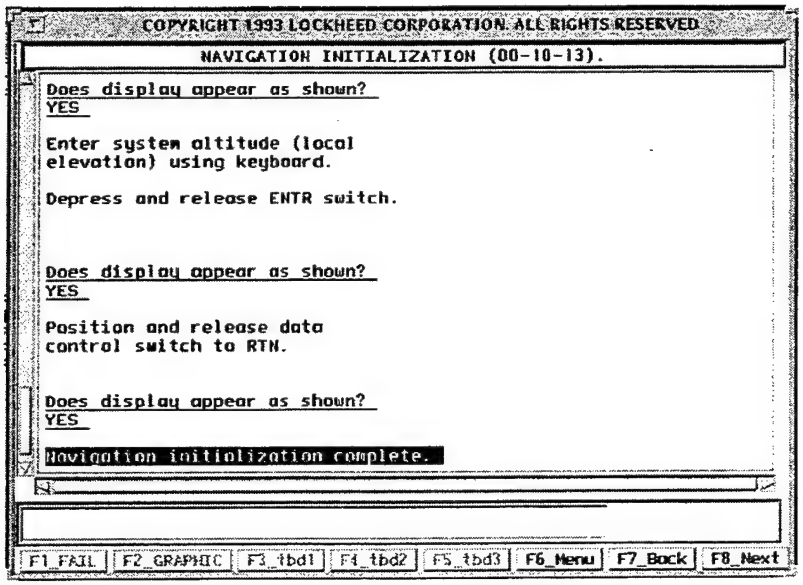

Fig. 59. The last screen of IMIS' verification check procedure, showing completed tasks and operator input.

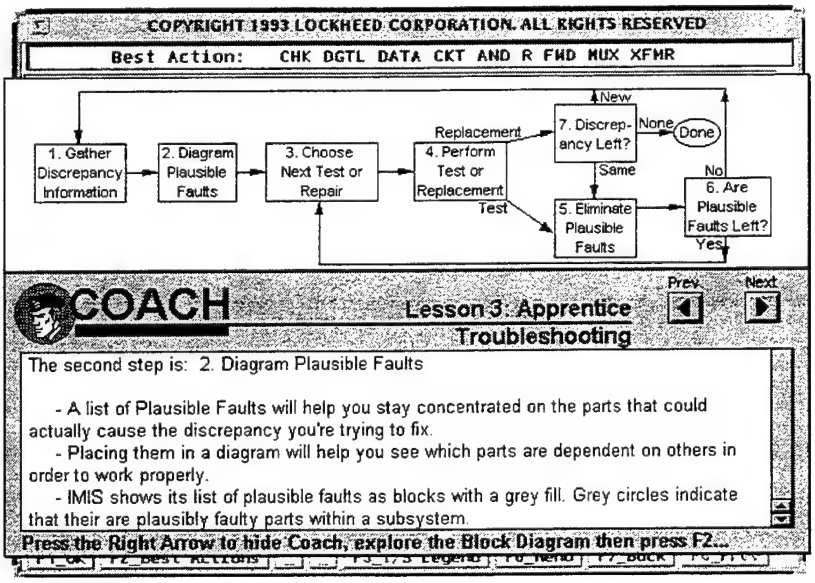

Fig. 60. COACH relates IMIS block diagrams to the step two of the troubleshooting model.

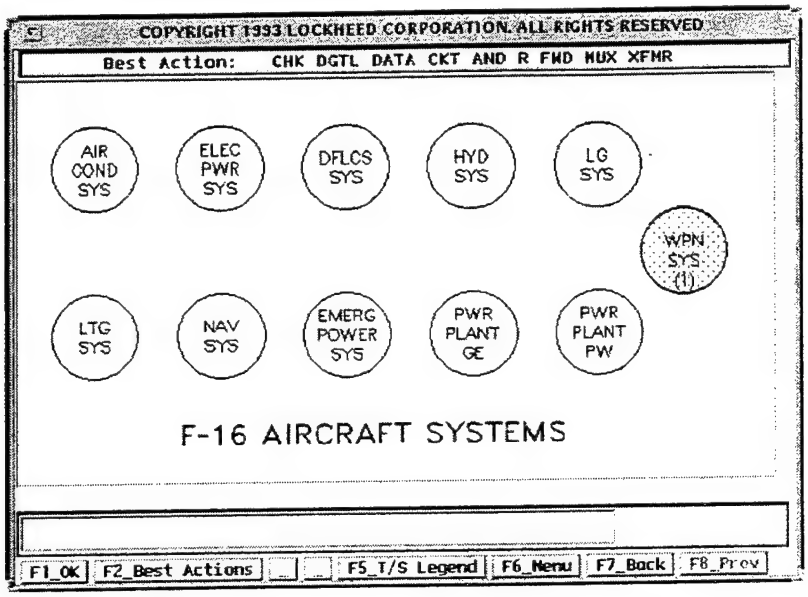

Fig. 61. IMIS block diagram for fault code 94-61-AD— Fire Control Radar. Notice the half-tone shading on "WPN SYS", showing that it contains plausibly faulty parts.

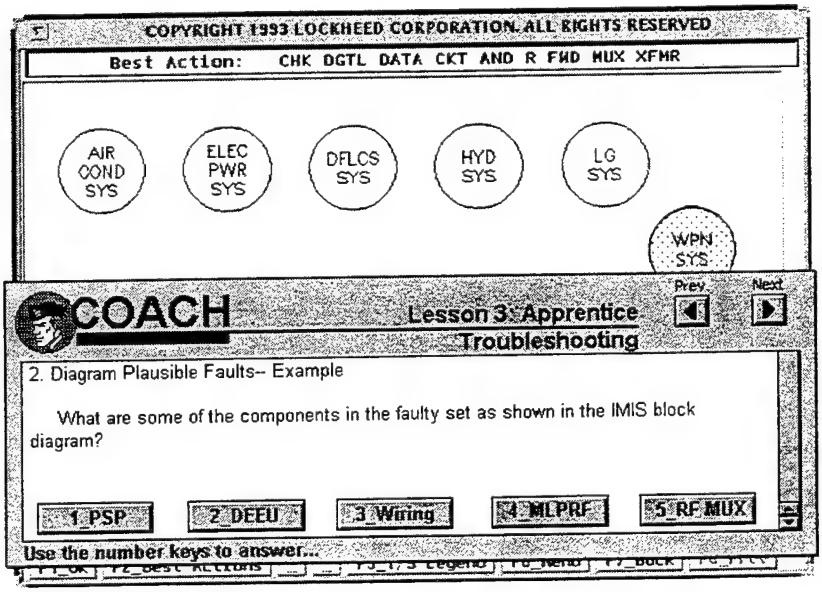

Fig. 62. Embedded test question: student should have found parts 1, 3, and 5 in the IMIS plausibly faulty set.

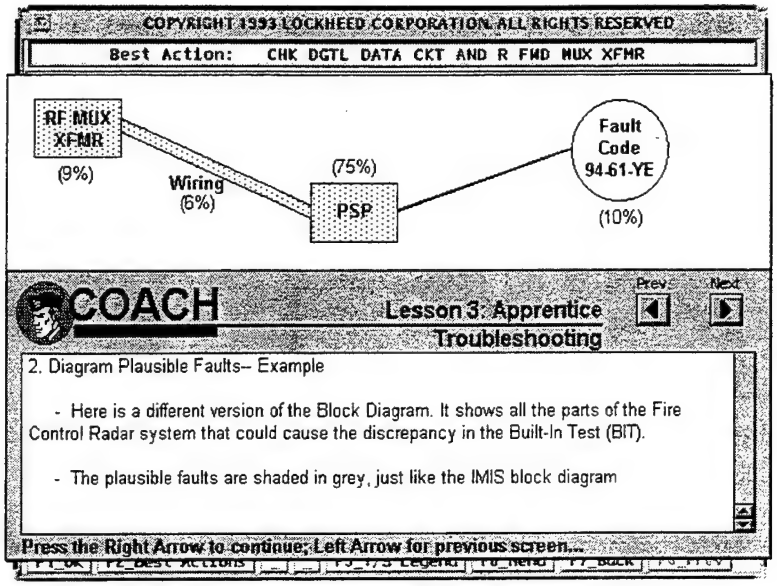

Fig. 63. COACH introduces a simplified block diagram (mental model). The COACH integrates failure probability data from the CDM to aid the decision process.

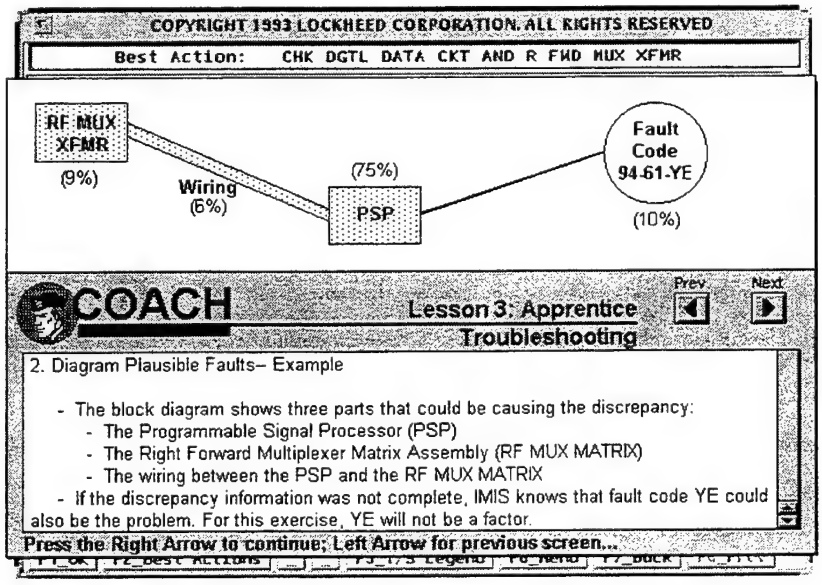

Fig. 64. The COACH defines the components of the simplified block diagram.

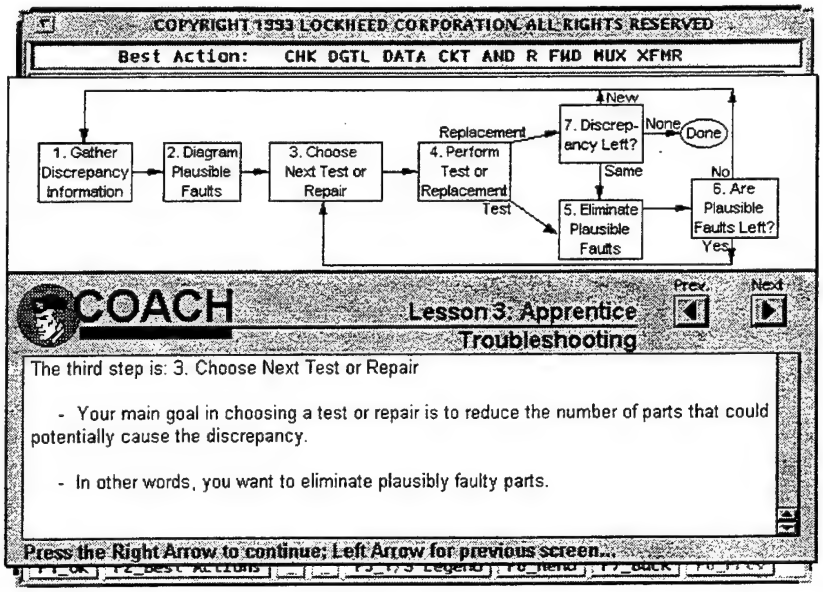

Fig. 65. The COACH explains step three in the troubleshooting model.

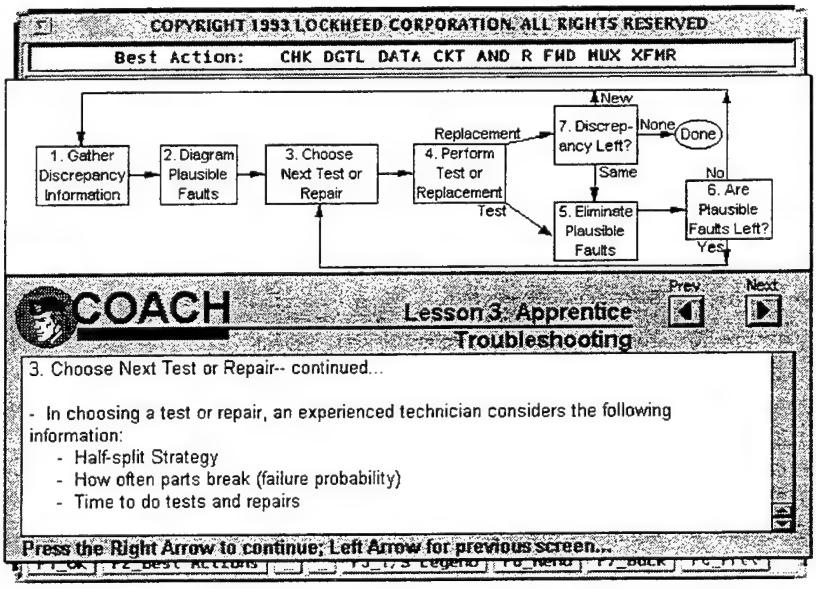

Fig. 66. The COACH explains the key data elements for test selection.

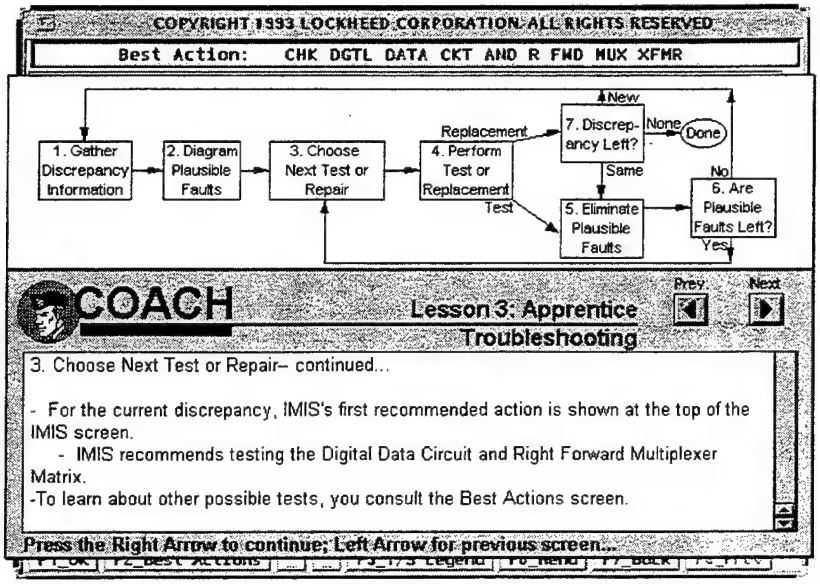

Fig. 67. The COACH introduces IMIS' Best Action screen.

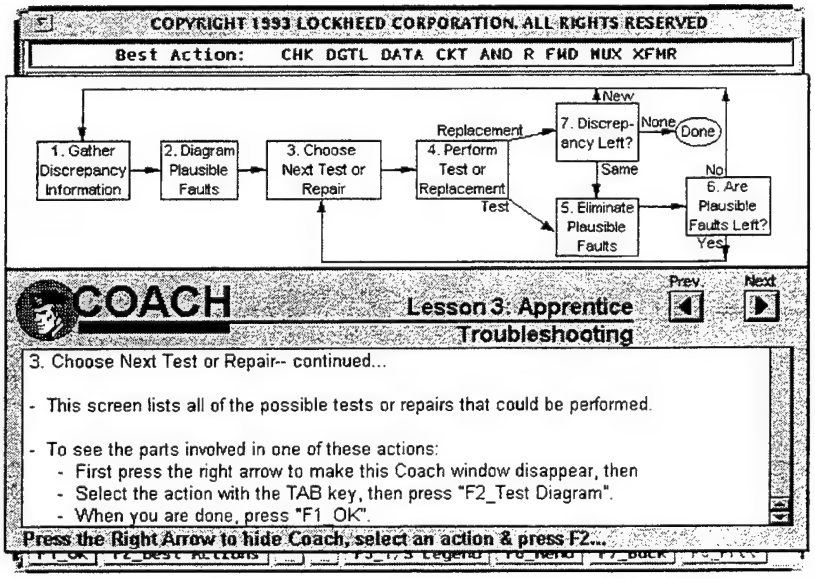

Fig. 68. The COACH tells the student how to work with IMIS' Best Action screen.

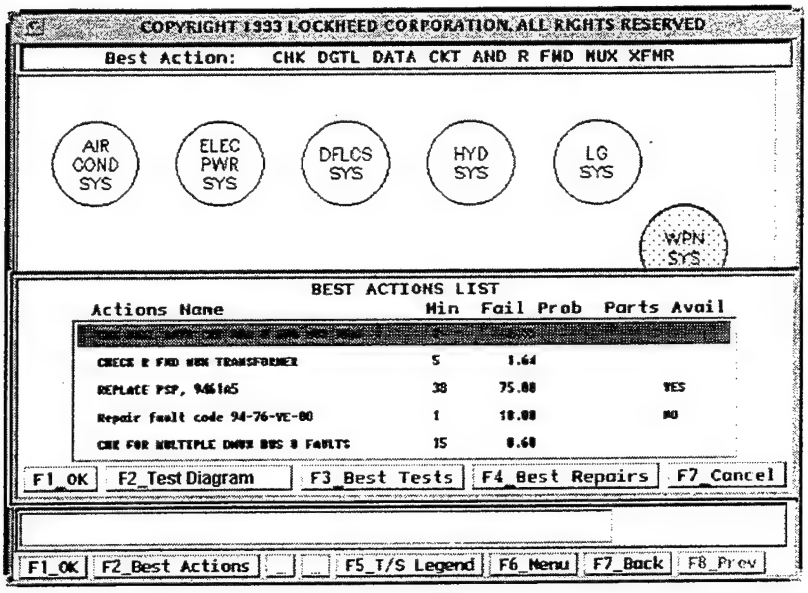

Fig. 69. IMIS' Best Action screen shows rank-ordered possible actions. Notice the "F2_Test Diagram" button added to IMIS' Best Action screen. This can help diagnosticians with or without the COACH running.

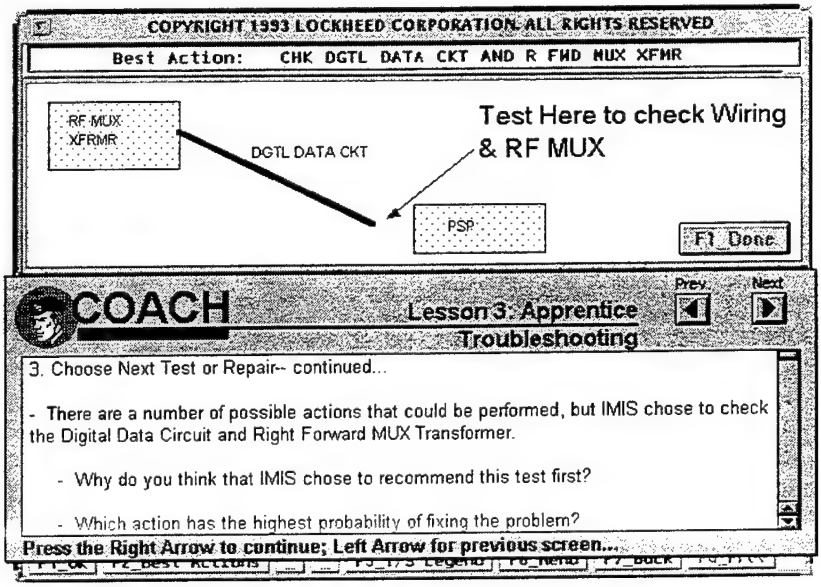

Fig. 70. COACH encourages student thought about test selection rationale. Notice that the simplified block diagram is now shown as an integrated IMIS display. We believe that simplified block diagrams for common faults should be added to the CDM for the benefit of both COACH and regular IMIS.

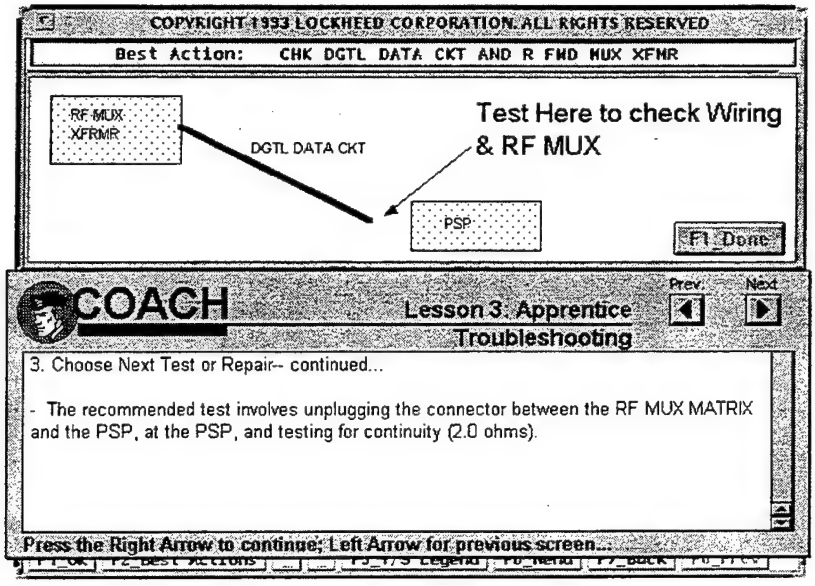

Fig. 71. COACH explains the test IMIS selected as the Best Action.

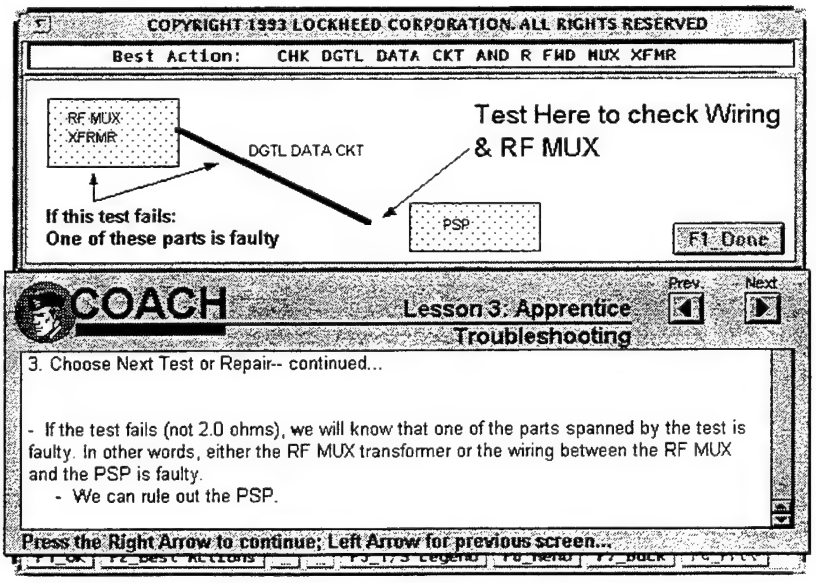

Fig. 72. COACH test explanations would have to be added to the CDM along with the simplified block diagrams to support these mental model building features.

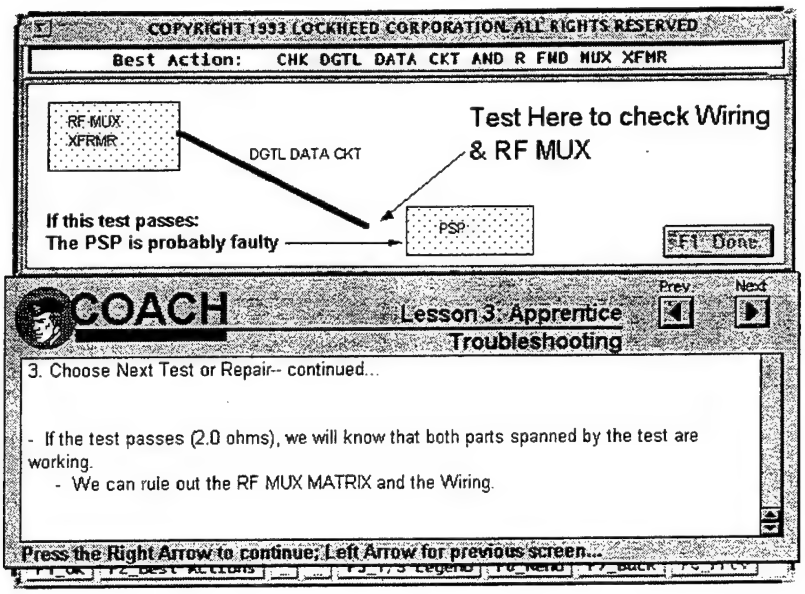

Fig. 73. Once added, the simplified block diagram will support both COACH instruction and standard IMIS troubleshooting.

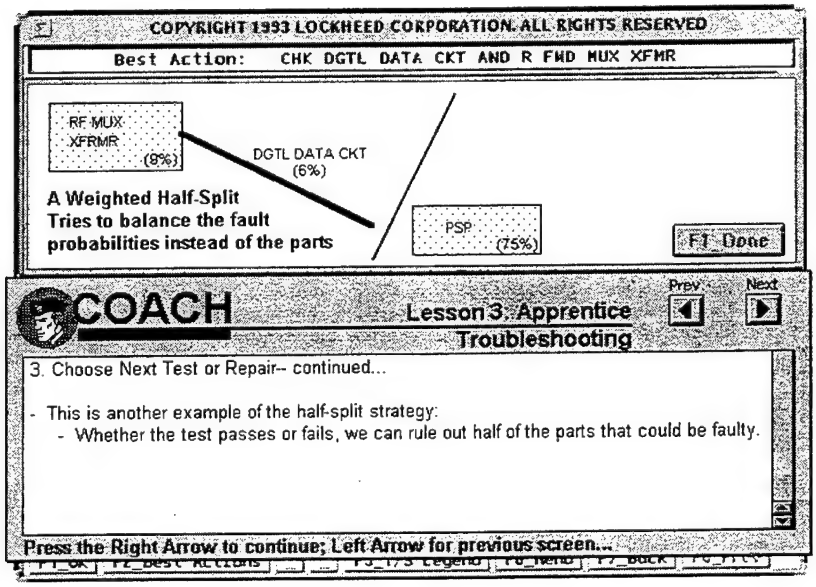

Fig. 74. COACH explains the weighted half-split concept, where the parts are divided by the sums of their fault probabilities and the time to conduct the different tests or repairs.

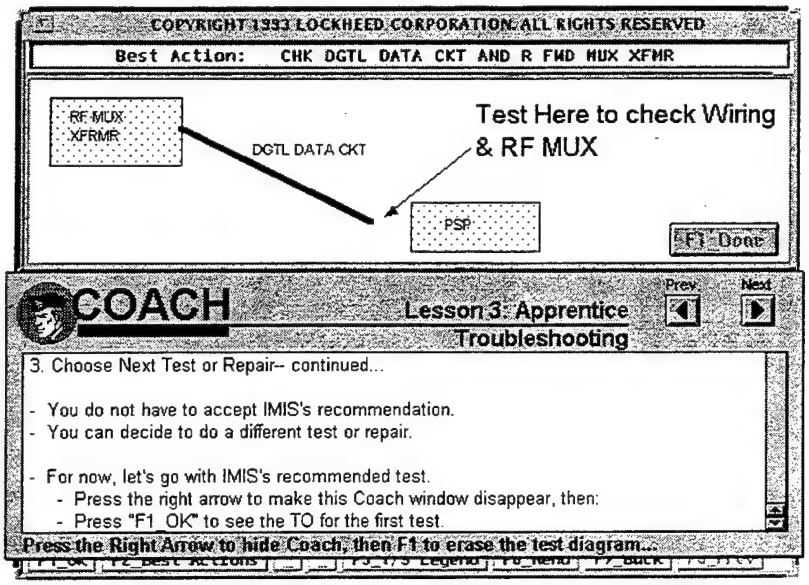

Fig. 75. COACH guides the Apprentice's test selection.

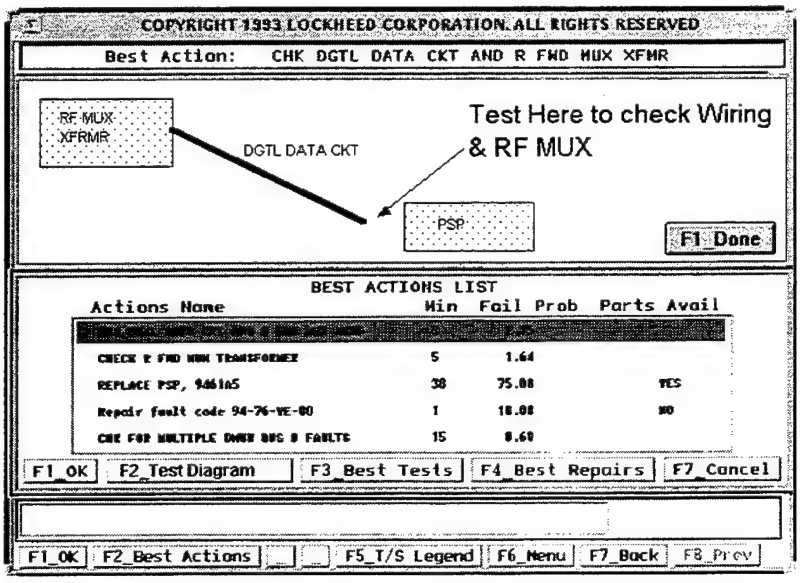

Fig. 76. The simplified mental model diagram works well with IMIS' Best Action screen (whether or not COACH is running).

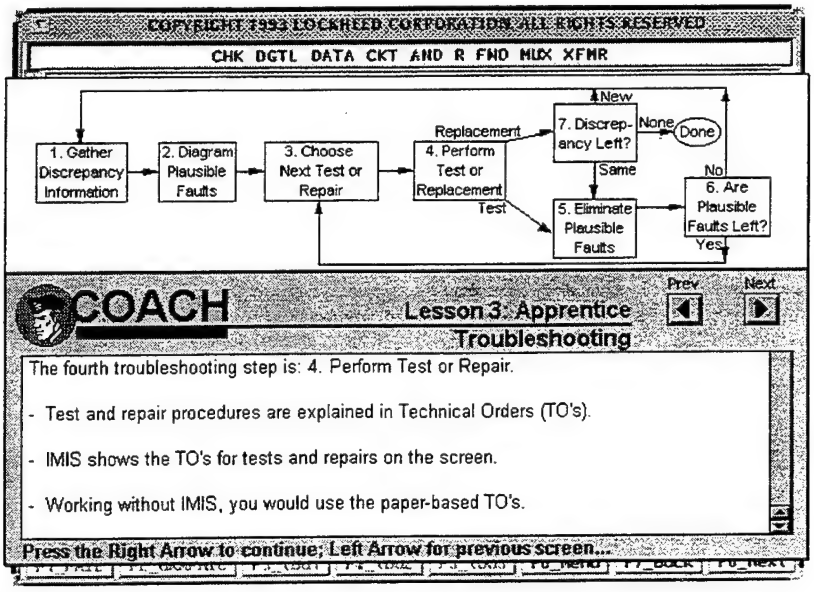

Fig. 77. COACH relates the fourth step in the troubleshooting model to IMIS' diagnostic process.

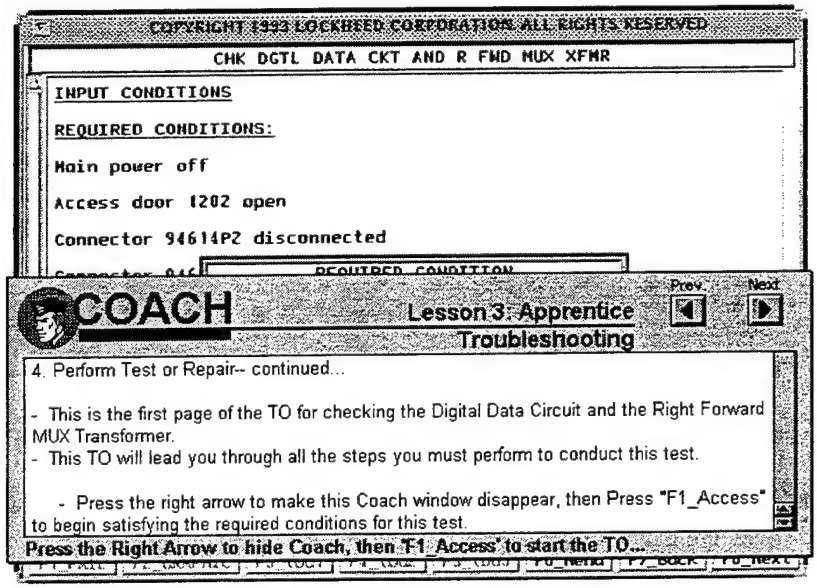

Fig. 78. COACH explains the next phase of diagnostic performance with IMIS.

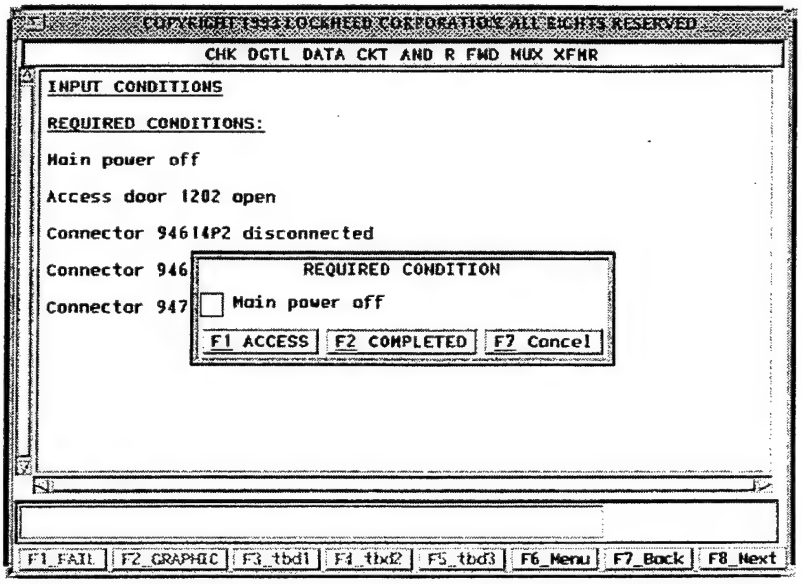

Fig. 79. Part of an IMIS-based Technical Order.

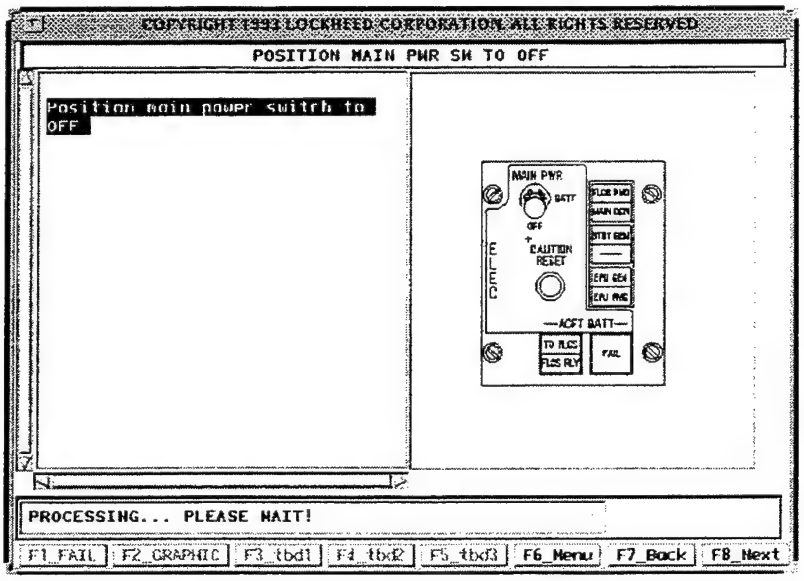

Fig. 80. Part of an IMIS-based Technical Order.

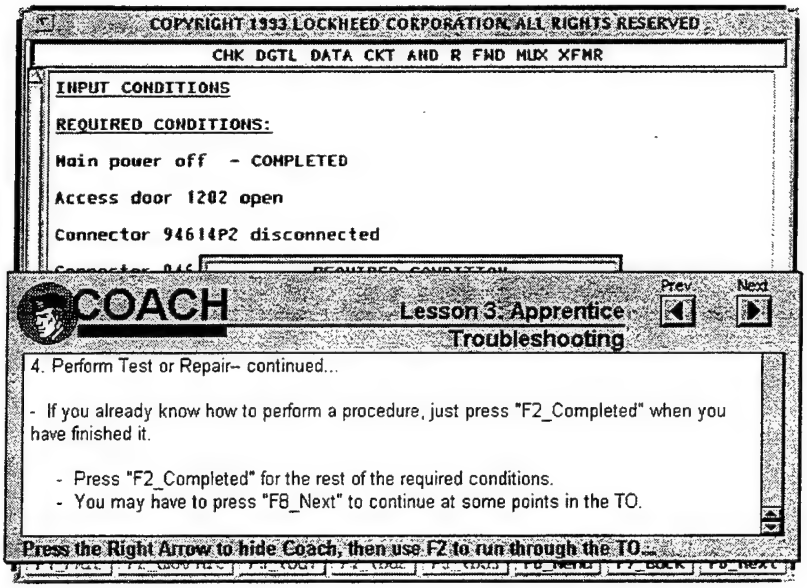

Fig. 81. COACH can also give advice on how to use IMIS more efficiently.

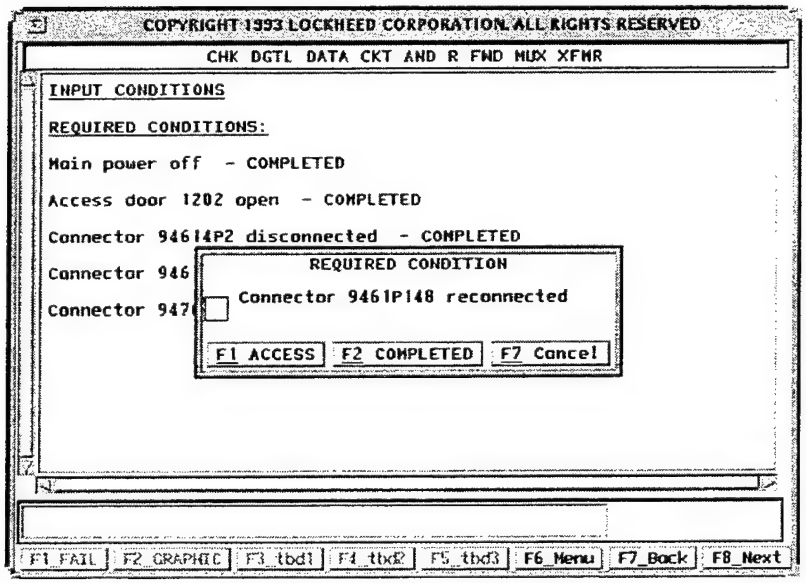

Fig. 82. In a simulation with no external equipment (stand alone mode), the student moves quickly through the testing TO with the F2 key. The student can still access and explore the test and repair procedures if time permits.

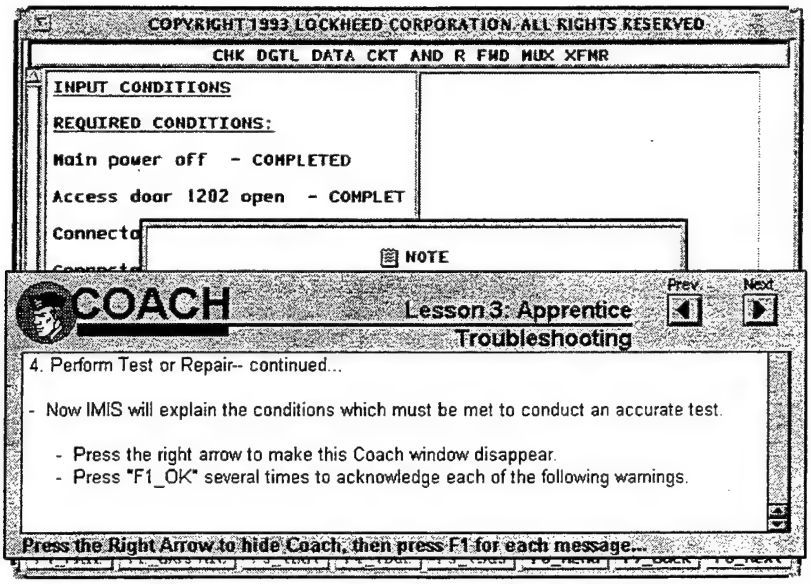

Fig. 83. The student is ready to conduct the test. The COACH intercedes to explain what will happen.

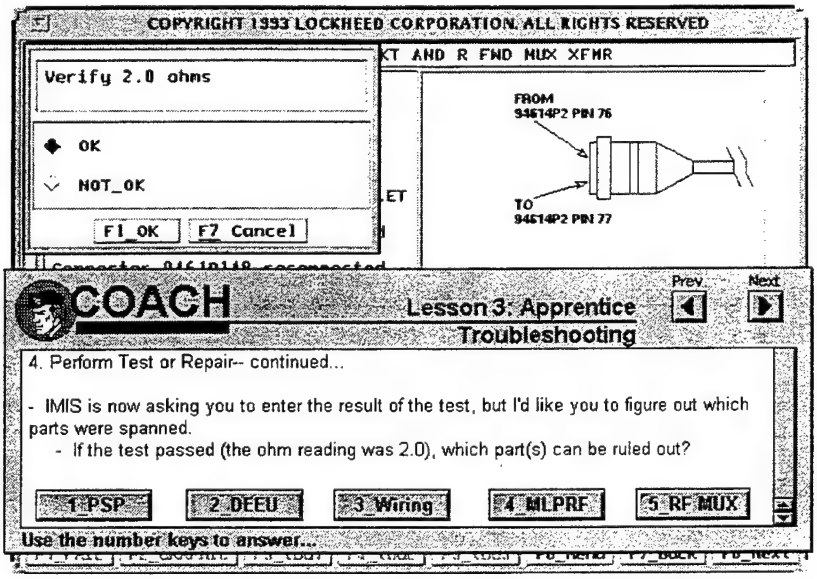

Fig. 84. An IMIS test setup screen.

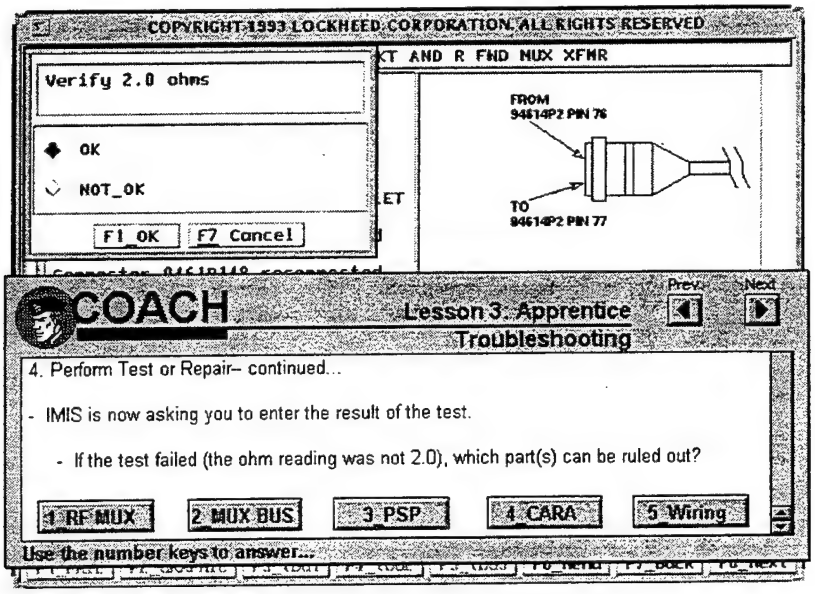

Fig. 85. Before the student enters the result of the test, COACH asks for a prediction of which parts can be eliminated if the test *passes*.

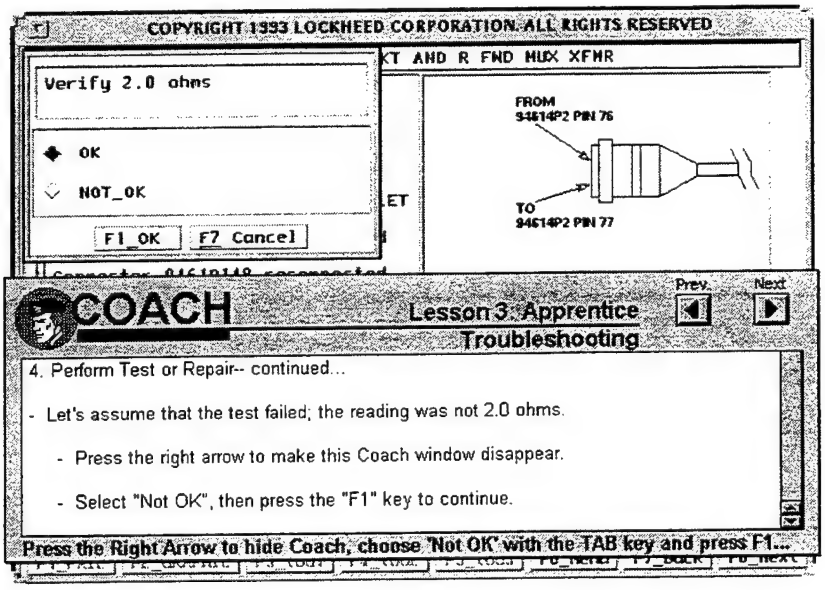

Fig. 86. Before the student enters the results of the test, COACH also asks for a prediction of which parts can be eliminated if the test *fails*.

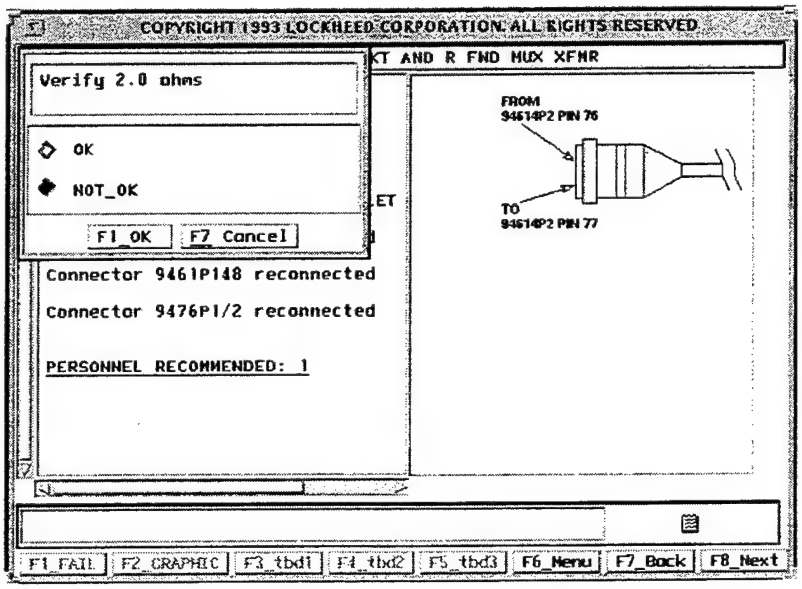

Fig. 87. In stand alone mode, COACH provides the results of the simulated test for the student to enter into IMIS.

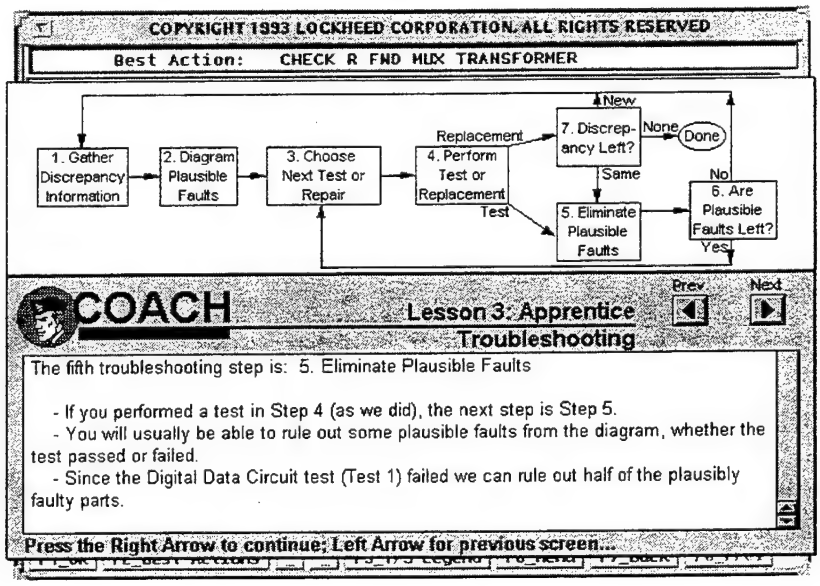

Fig. 88. IMIS test result entry dialog box.

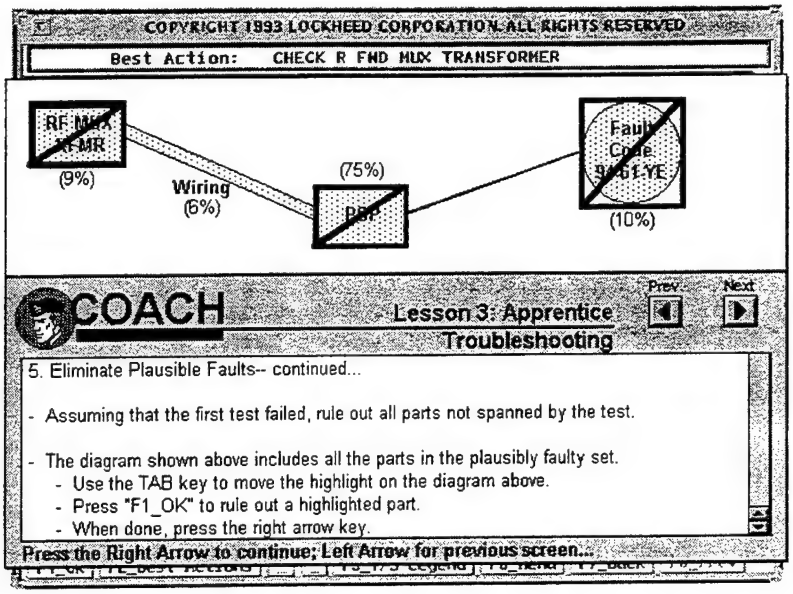

Fig. 89. The COACH shows how step five in the troubleshooting model relates to IMIS' diagnostic process.

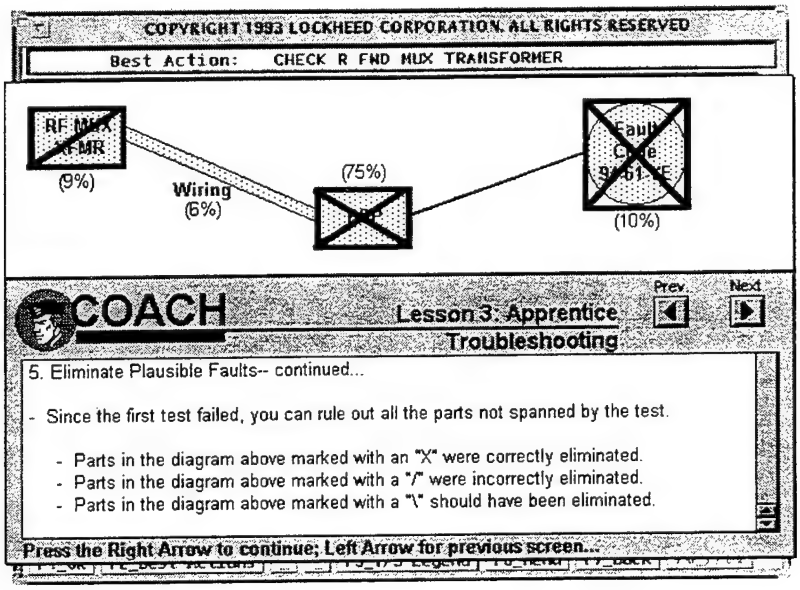

Fig. 90. COACH asks the student to eliminate components on the simplified block diagram which correspond to the failure of the first test.

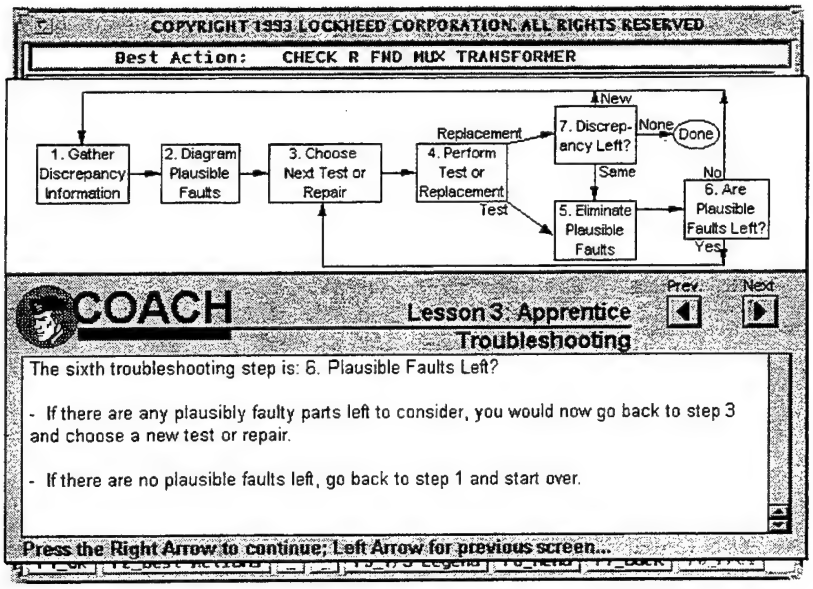

Fig. 91. IMIS feedback on student parts selection. In this case, the student failed to eliminate any parts. PSP and Fault Code YE should have been eliminated.

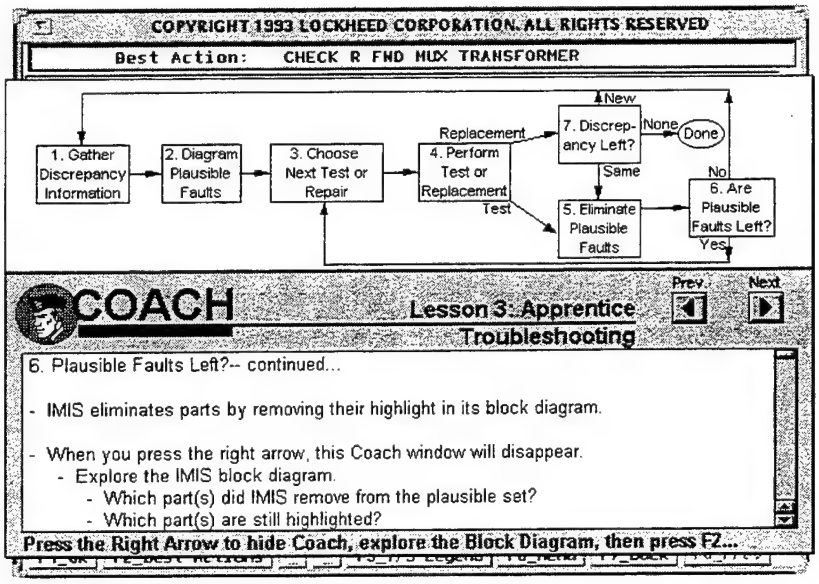

Fig. 92. COACH relates the sixth step in the troubleshooting model to the IMIS diagnostic process.

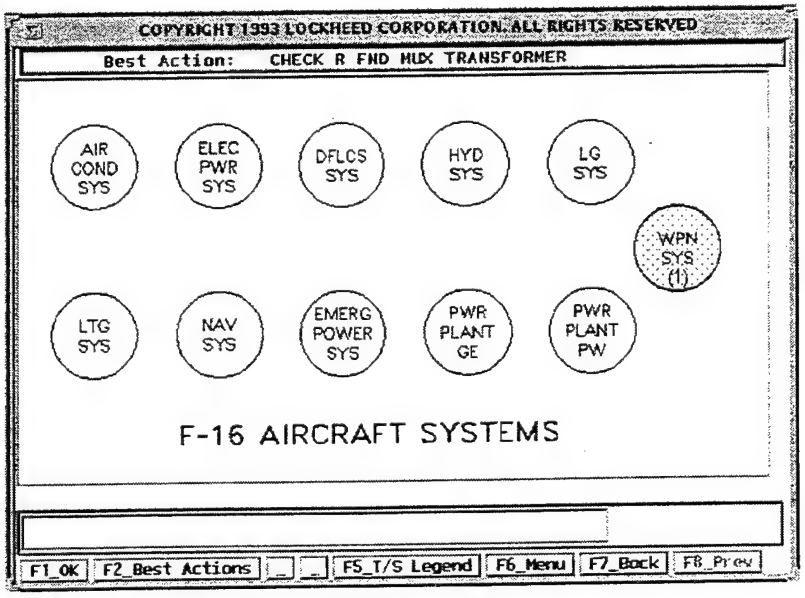

Fig. 93. COACH relates the sixth step in the troubleshooting model to the IMIS diagnostic process.

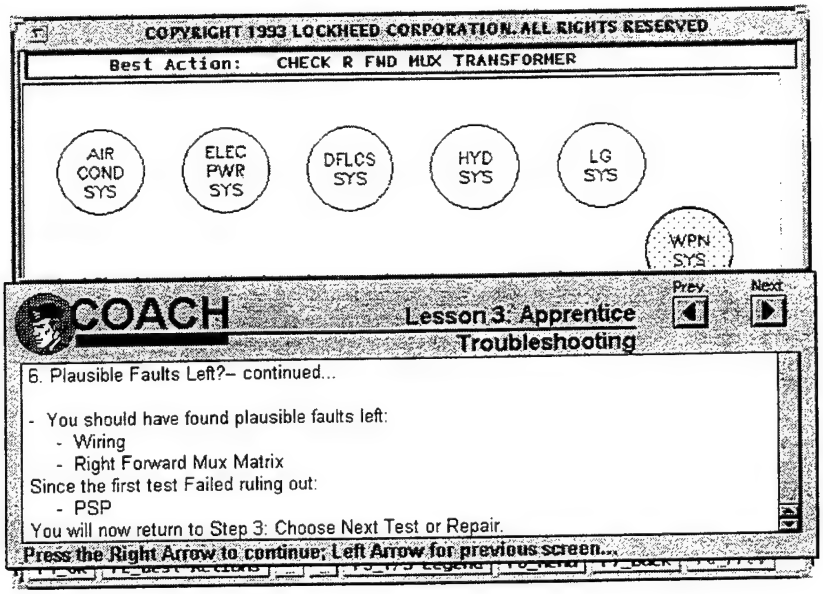

Fig. 94. When IMIS' Troubleshooting block diagram is shown, the student is encouraged to explore it to determine which parts remain in the plausibly faulty set. This also helps reinforce procedures for diagnostic use of IMIS without COACH.

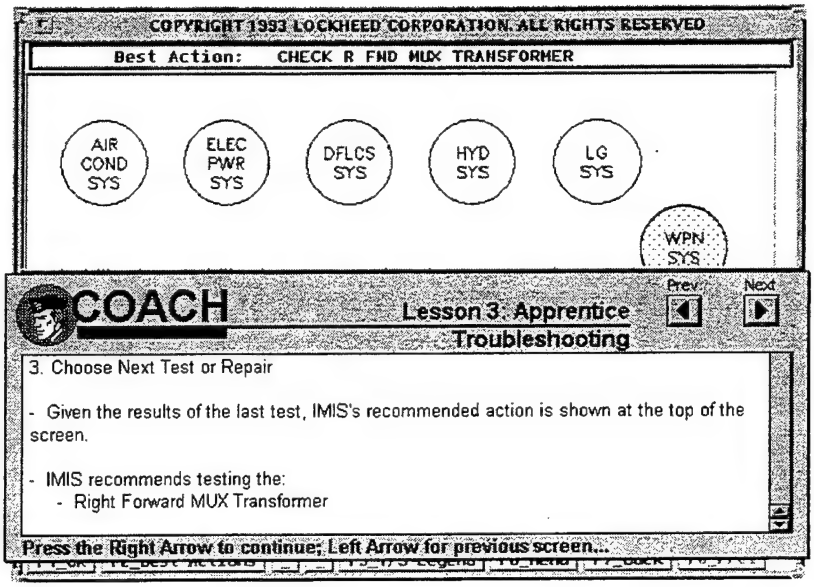

Fig. 95. When F2 is pressed to see IMIS' list of Best Actions, COACH automatically reappears to verify the plausibly faulty parts found by the student in the IMIS block diagram.

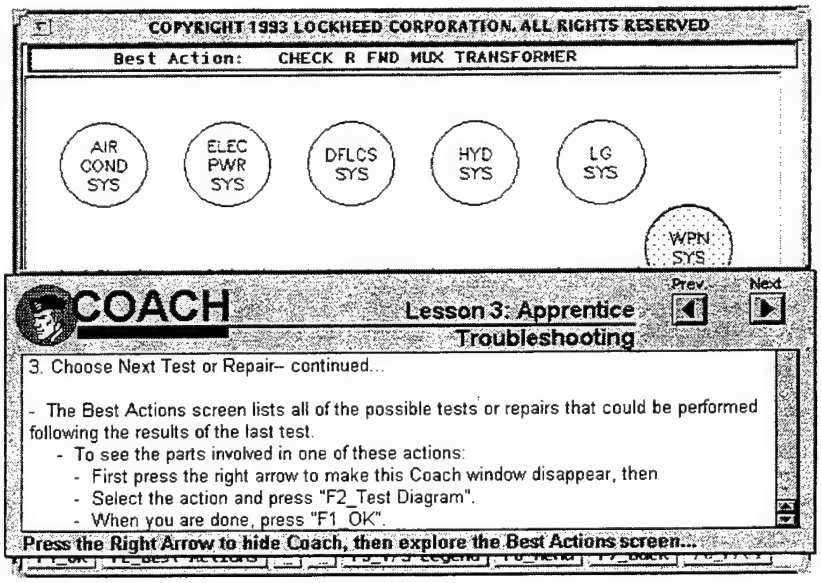

Fig. 96. COACH reveals IMIS' Best Action for the second test cycle. Notice that the COACH messages are identical to those presented during the first test cycle. Only the name of the current Best Action is substituted into the generic COACH message.

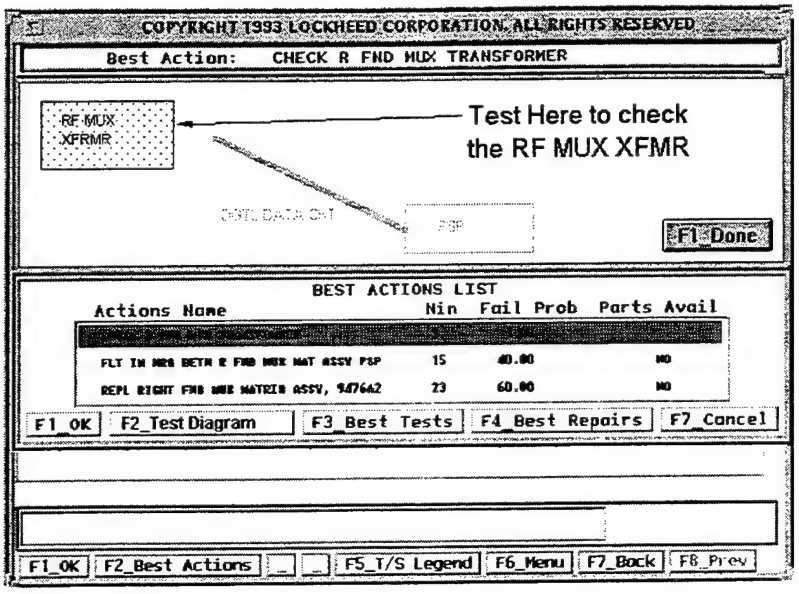

Fig. 97. COACH uses mostly generic messages that will work with any fault code. This should make programming COACH much faster.

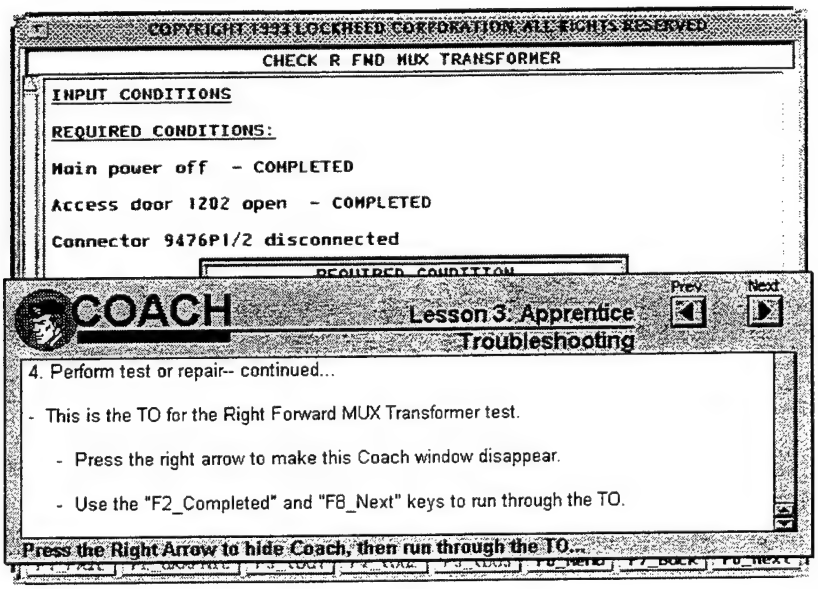

Fig. 98. COACH applies IMIS' standard highlighting techniques to the simplified block diagram to focus student attention on the part to be tested. In the Apprentice level, only the recommended test can be chosen.

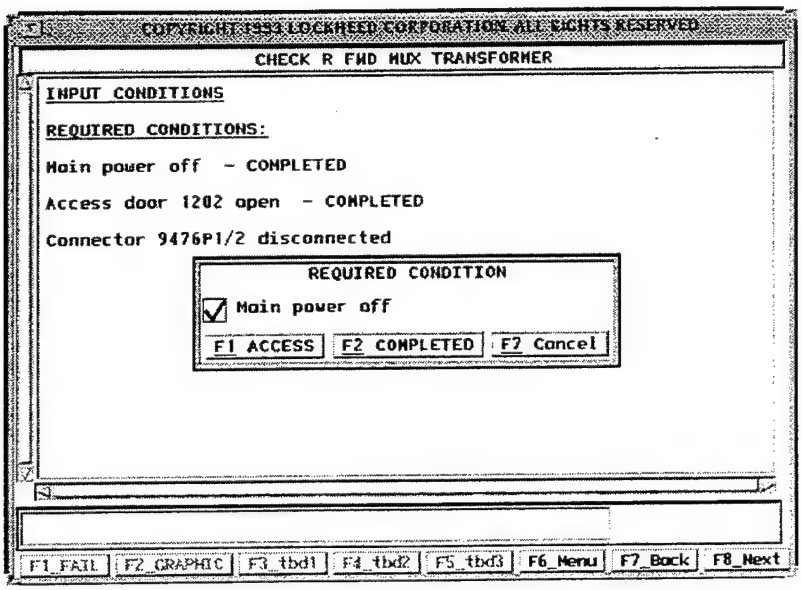

Fig. 99. COACH prepares the Apprentice for the second test cycle.

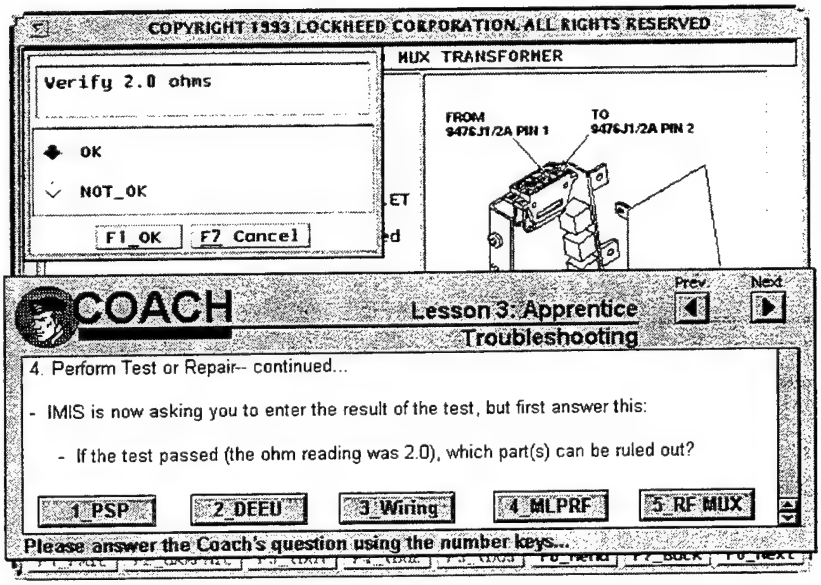

Fig. 100. The first screen of IMIS' second test Technical Order. We will now skip a number of screens.

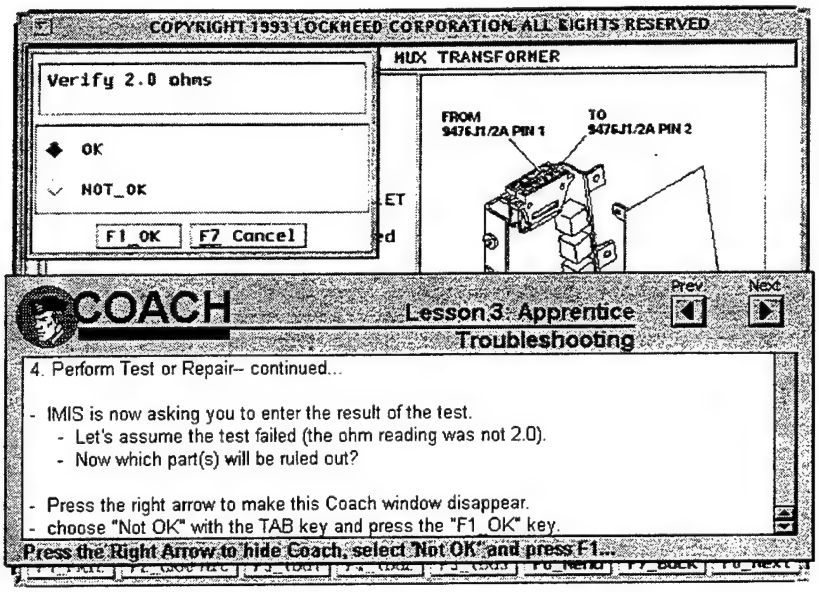

Fig. 101. Before the Apprentice enters the result of the second test, the COACH asks for a prediction of the parts that will be eliminated based on the test outcome.

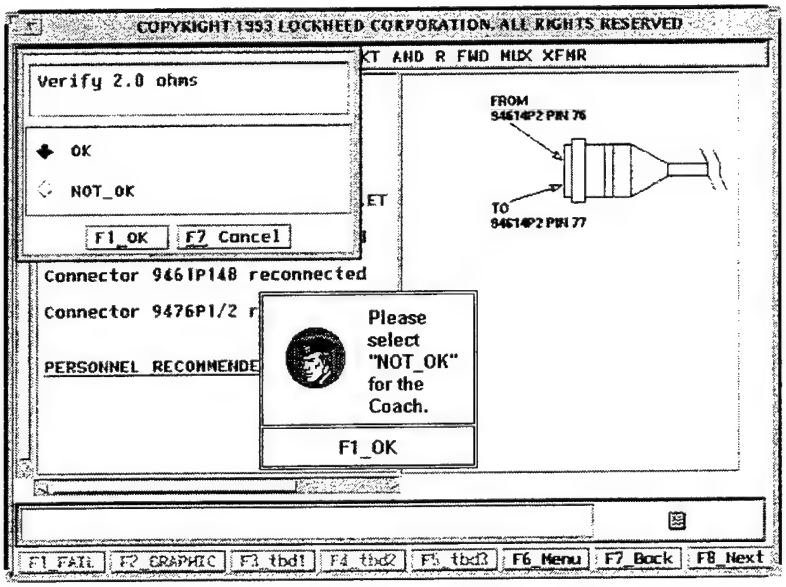

Fig. 102. In stand alone mode, the COACH provides the results of the tests since there is no actual equipment available to test. Notice the reuse of the same COACH screen as during the first test.

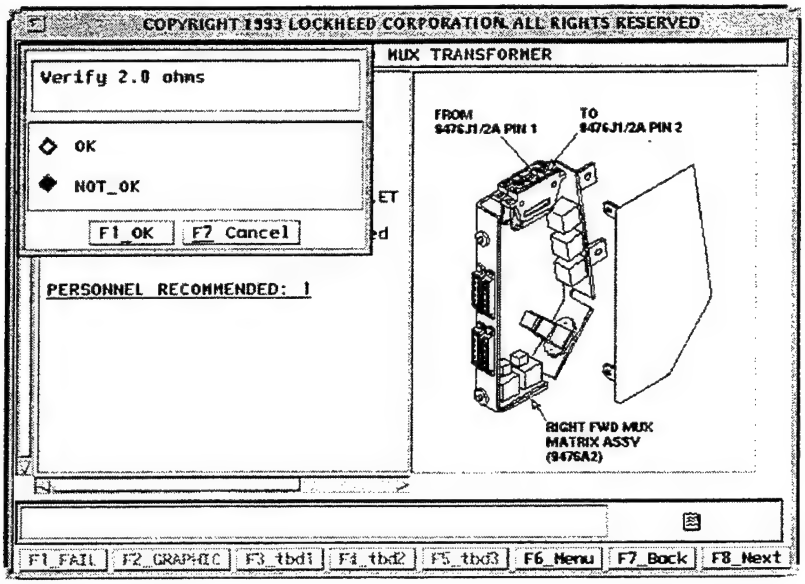

Fig. 103. Test two result entered in the IMIS test data collection dialog box.

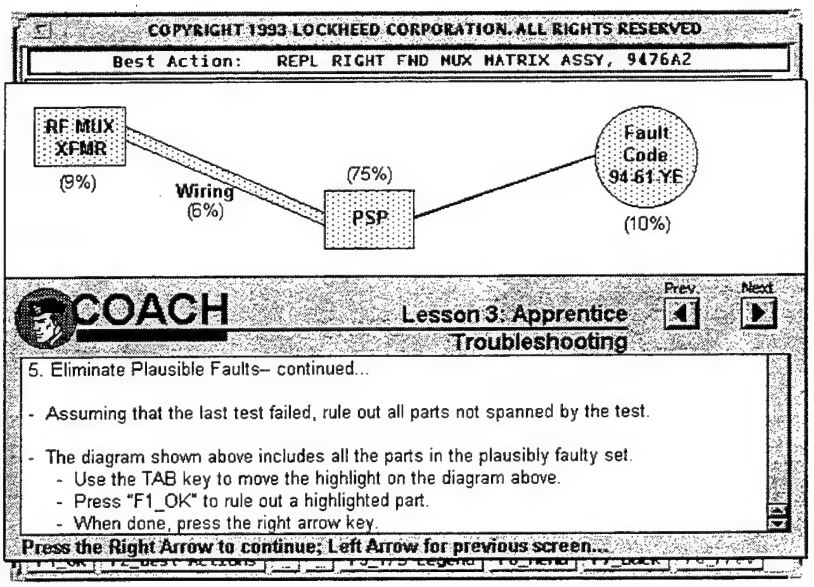

Fig. 104. Since there are still plausibly faulty components left, COACH repeats the process showing the student eliminated components on the simplified block diagram.

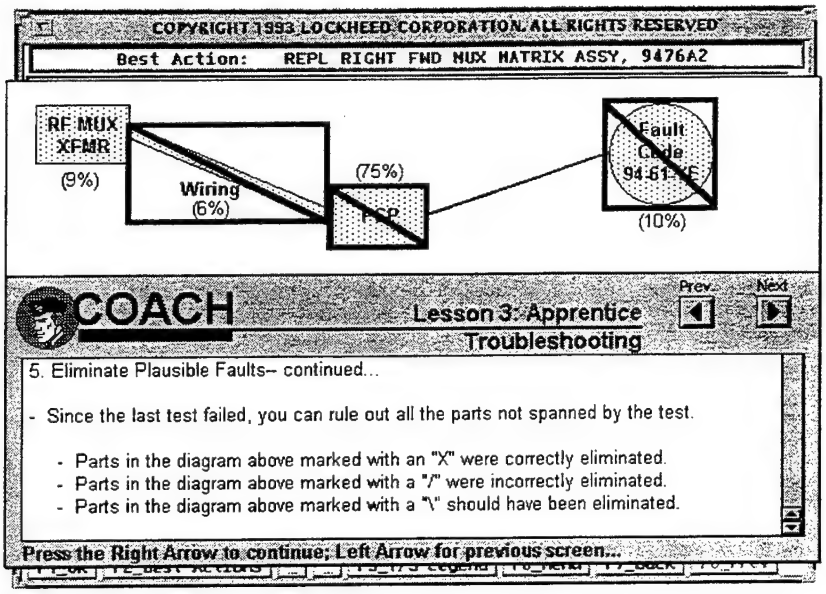

Fig. 105. With the eliminated parts ruled out, the student should have no problem understanding why the Right Forward Multiplex Transformer (RF MUX XFMR) should be replaced.

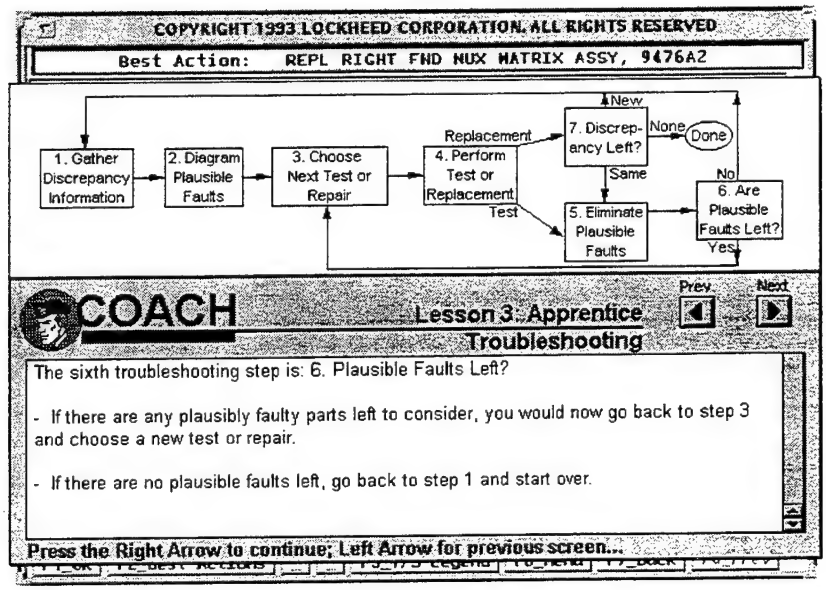

Fig. 106. The COACH explains how step six in the troubleshooting model is used by IMIS.

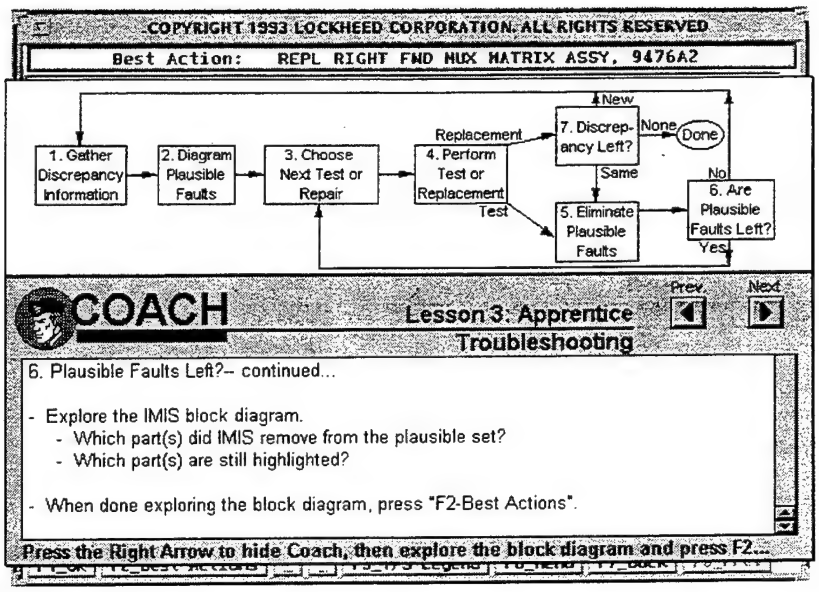

Fig. 107. The Apprentice is again asked to explore IMIS' block diagram to search for the remaining plausible faults. It is hoped this will build student skills for using IMIS as an information resource during troubleshooting, even if IMIS is in *degraded* mode.

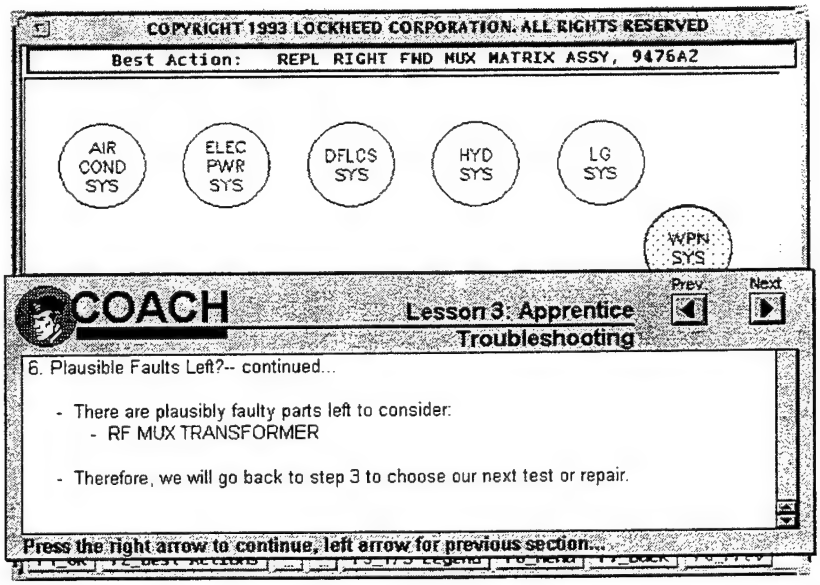

Fig. 108. COACH explains why the student must return to step three in the troubleshooting model.

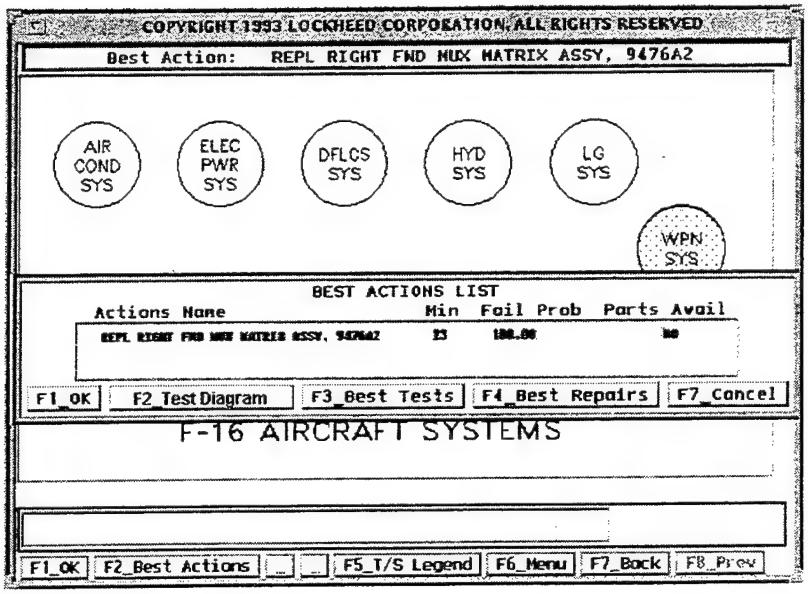

Fig. 109. Since there is only one plausibly faulty component left, IMIS' Best Action screen is actually a default action.

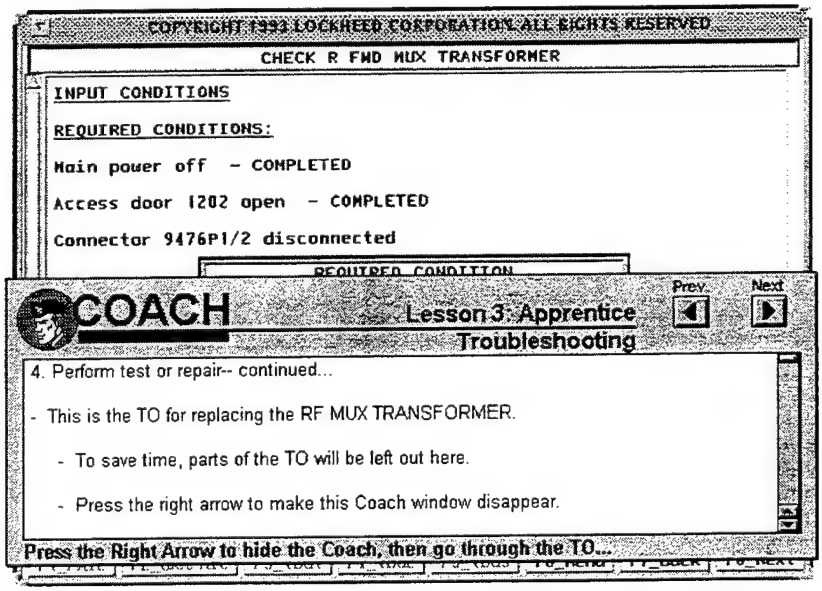

Fig. 110. In stand alone mode, the COACH can eliminate some parts of long TO's to save time and reduce tedium.

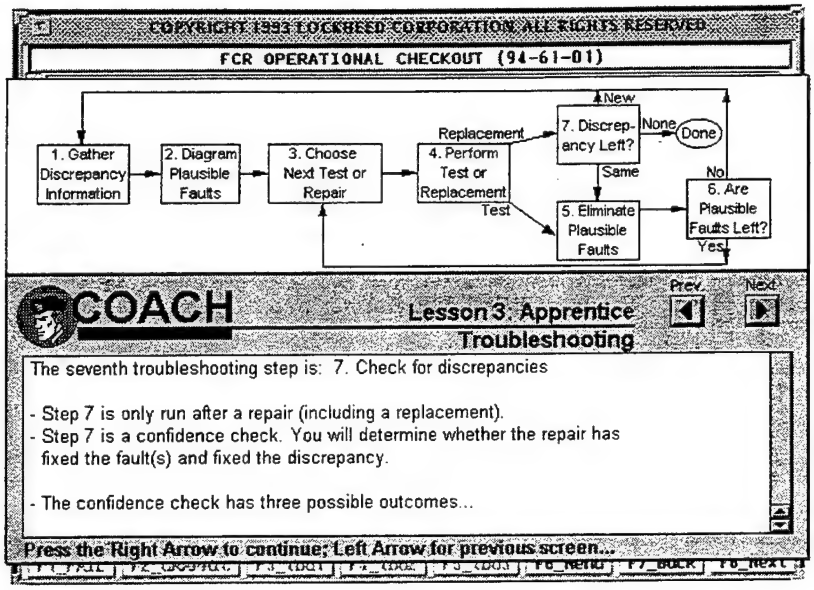

Fig. 111. COACH explains the purpose of the confidence check.

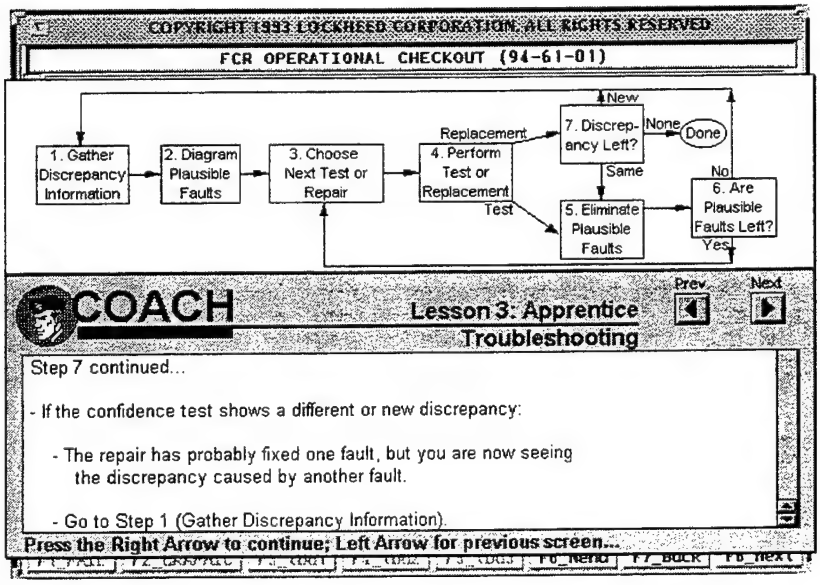

Fig. 112. COACH explains step seven of the troubleshooting model.

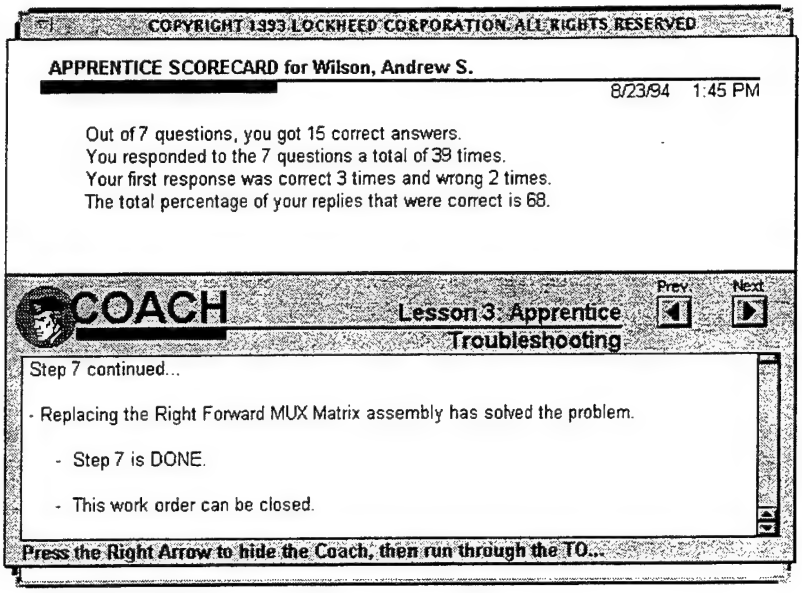

Fig. 113. The Lesson Three Apprentice final report shows the percentage of questions that were answered correctly as well as the number attempted and the raw score. Using IMIS's built-in recording capabilities, this report could also list each of the actions taken to solve the problem for student review.

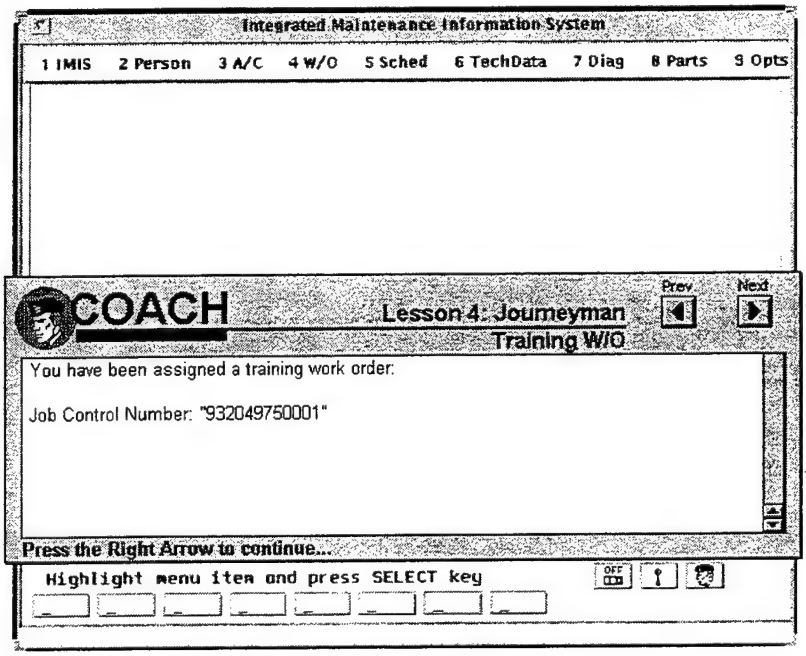

Fig. 114. The first screen of a Journeyman training scenario showing a preassigned training work order.

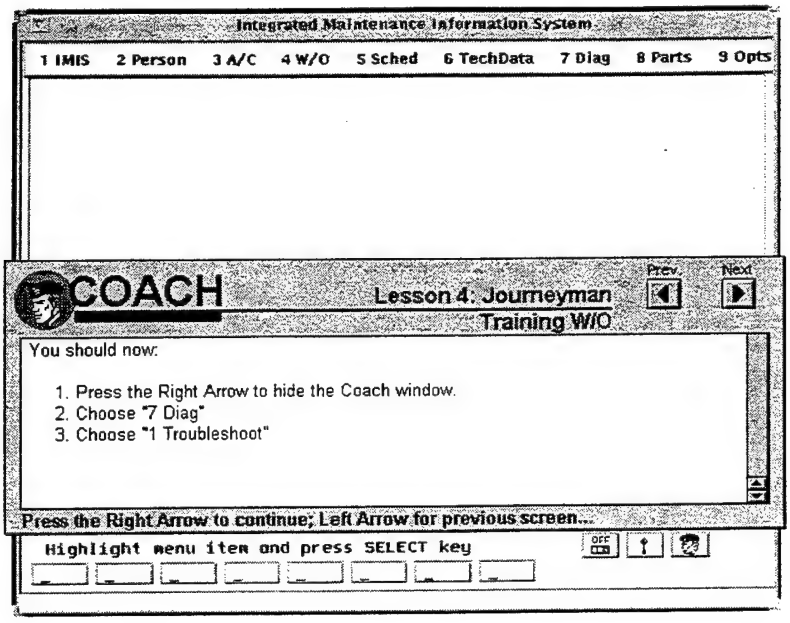

Fig. 115. COACH explains how to start the Journeyman level training work order.

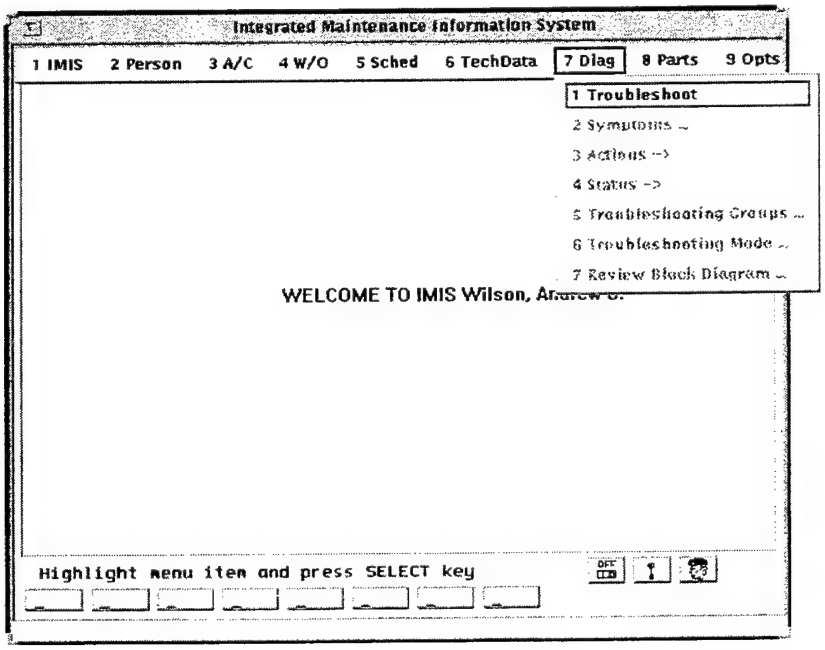

Fig. 116. Beginning an IMIS troubleshooting session.

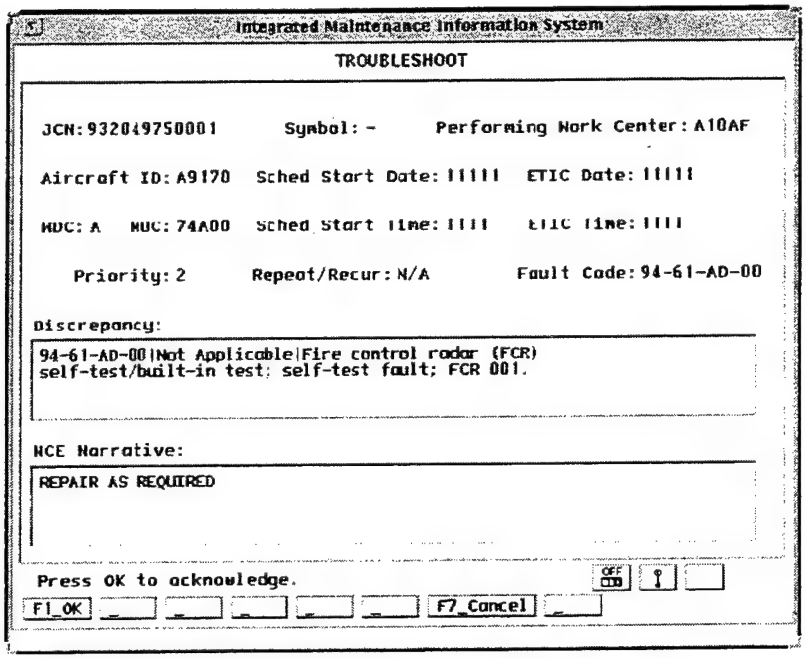

Fig. 117. COACH does not explain IMIS screens at the Journeyman level. It is assumed that the student is already familiar with IMIS screens and proficient with basic IMIS procedures.

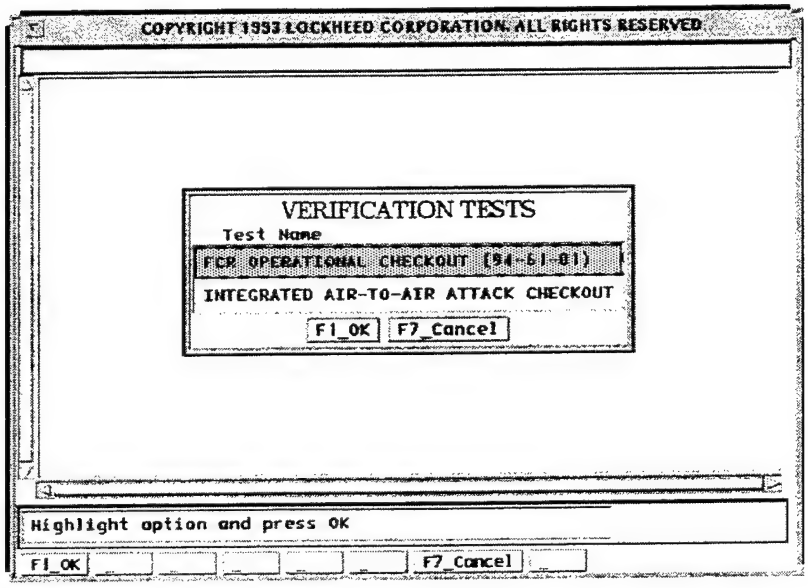

Fig. 118. It is up to the Journeyman to run the verification procedure without COACH's help.

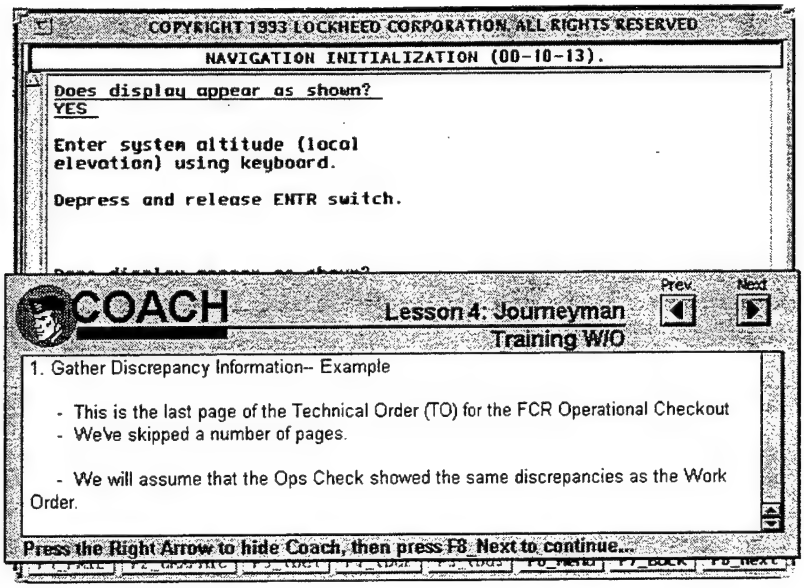

Fig. 119. In stand alone mode the verification test can be skipped since there is no actual equipment to test. In this case, the COACH confirms for the student that the verification check confirmed the original discrepancy.

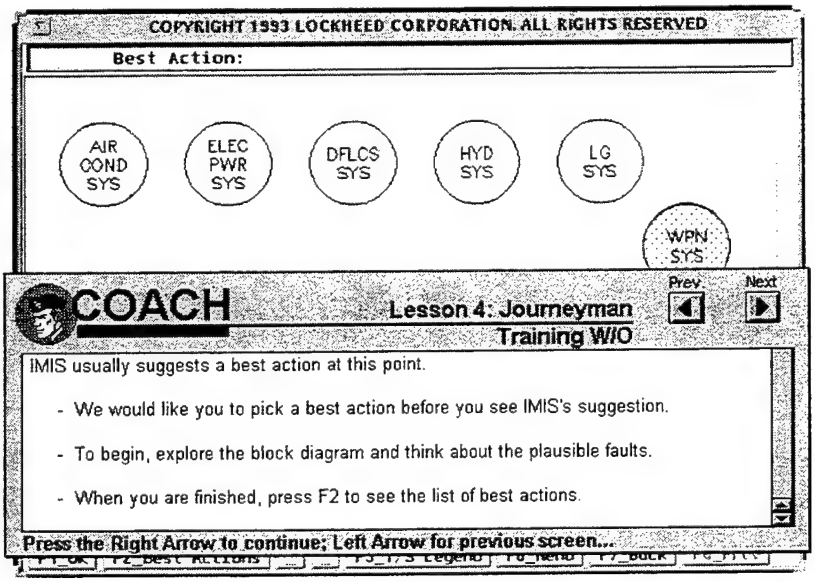

Fig. 120. The COACH explains that the Journeyman will be selecting the Best Action as his own.

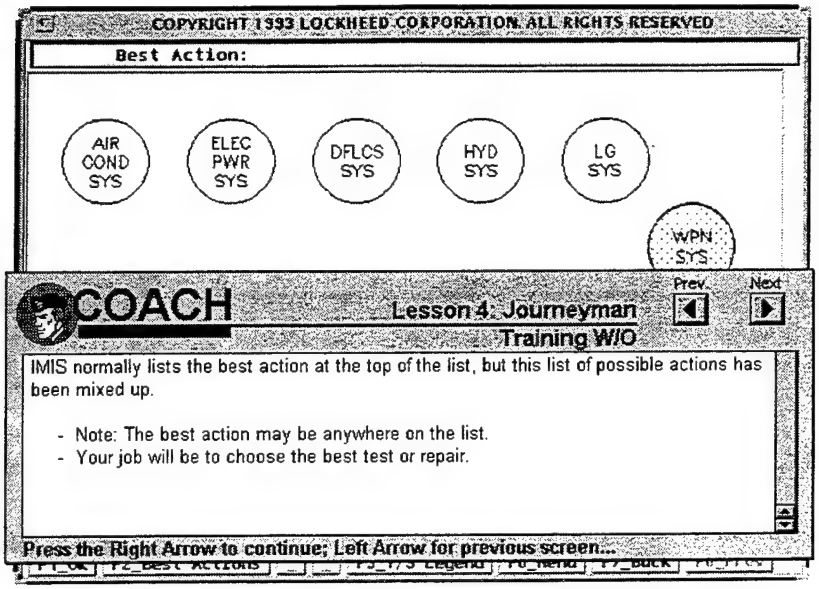

Fig. 121. The COACH explains that IMIS' Best Action list has been randomized to make selecting the best test or repair more of a challenge for the student.

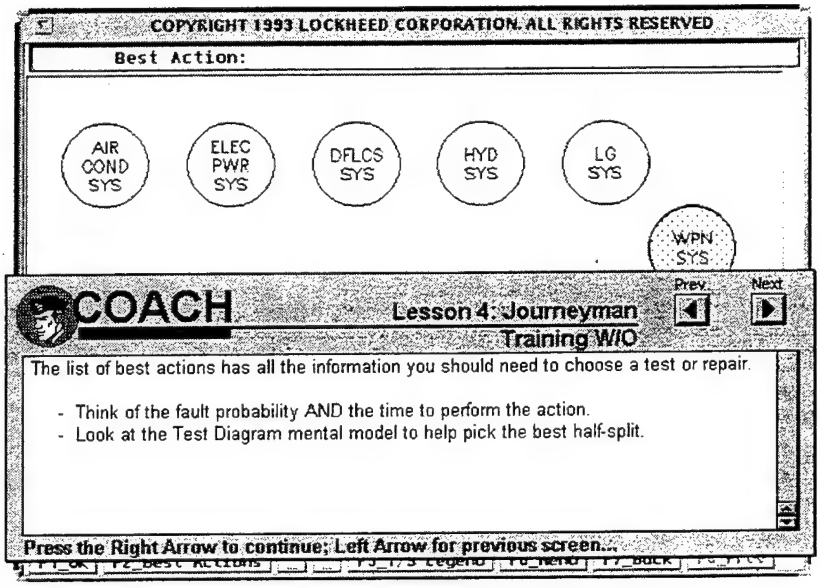

Fig. 122. COACH reminds the Journeyman of the strategies to use in selecting the best test or repair.

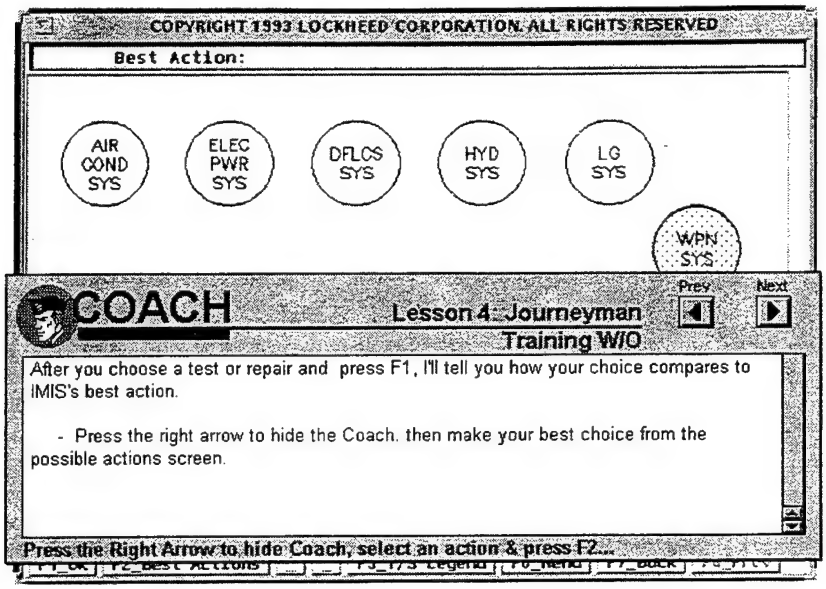

Fig. 123. After the student selects the best action, COACH will explain the merit or problems for the choice.

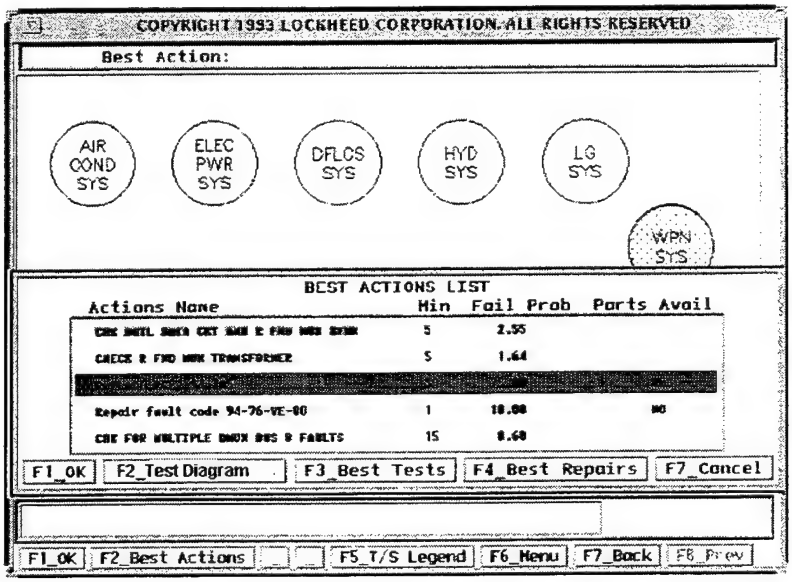

Fig. 124. For the prototype of COACH, the Best Actions list has *not* actually been randomized. This is for the benefit of presenters who need to know what the best action is during demonstrations.

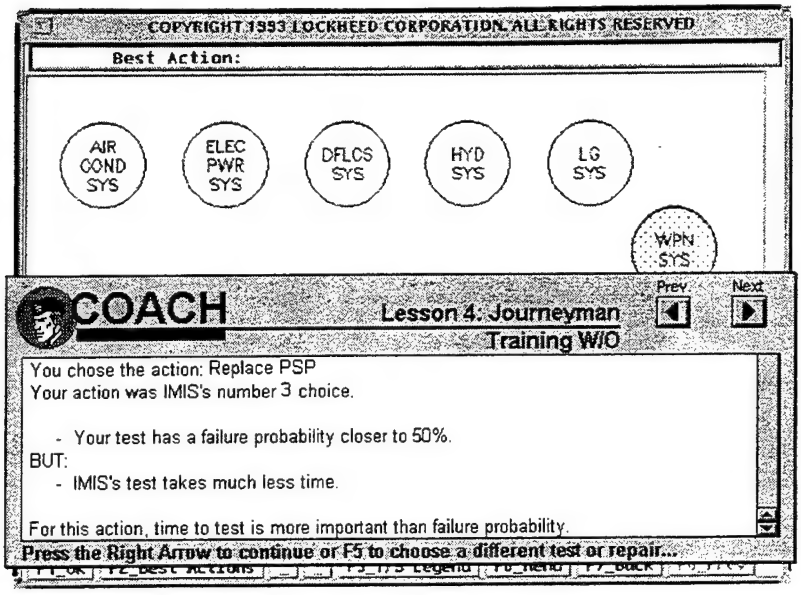

Fig. 125. The COACH explains why IMIS would have chosen a different test. The Journeyman has the option of keeping the original choice or returning to IMIS' Best Action screen and making a different selection.

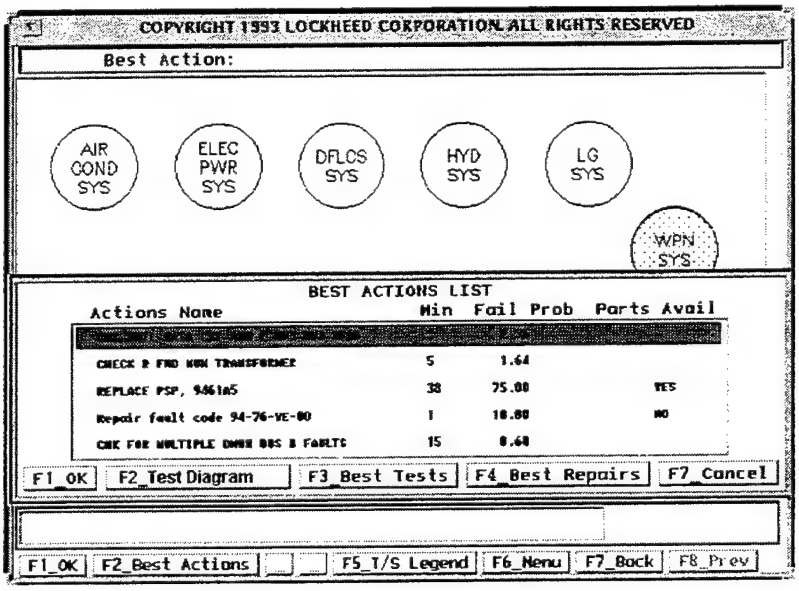

Fig. 126. The student selects the correct best action at this decision point.

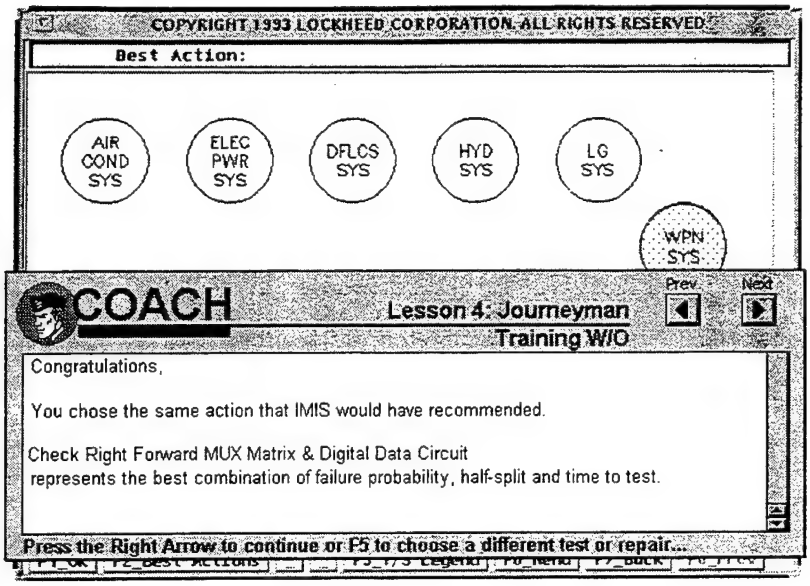

Fig. 127. COACH explains why IMIS selected this test or repair as the best action.

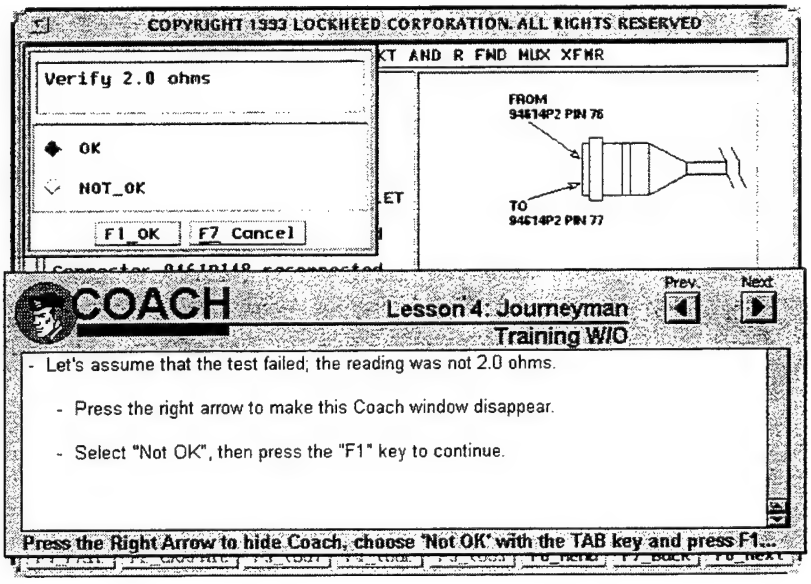

Fig. 128. After completing the test procedure Technical Order, COACH in stand alone mode provides the student with the test result to enter.

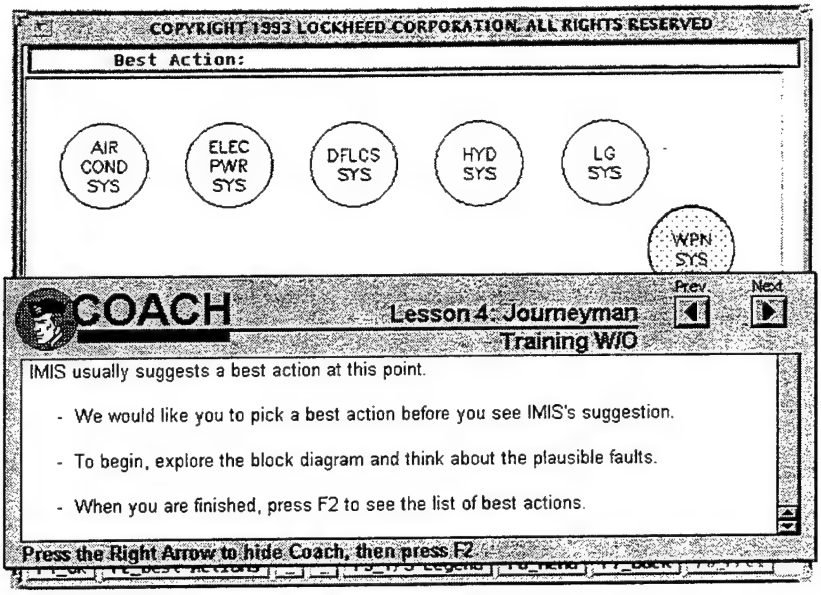

Fig. 129. The second test cycle begins. COACH encourages the student to explore the IMIS block diagram to learn which plausibly faulty components remain.

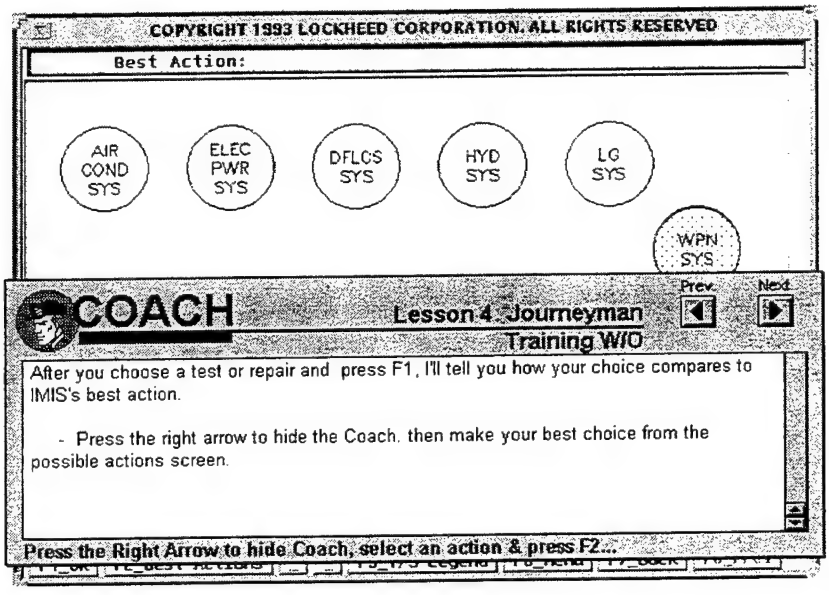

Fig. 130. COACH is reusing the same generic instructions it used for the first test cycle.

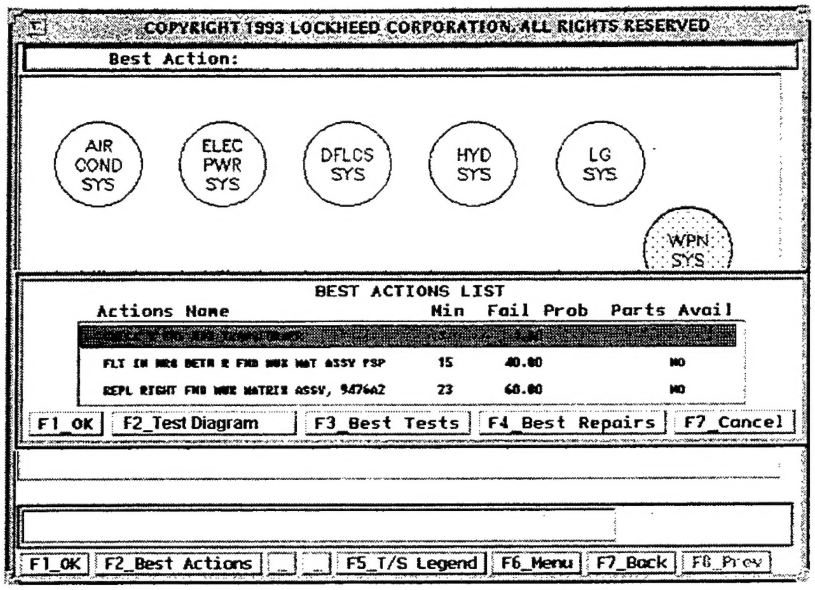

Fig. 131. The second Best Actions list. For the prototype COACH, this list has *not* been randomized.

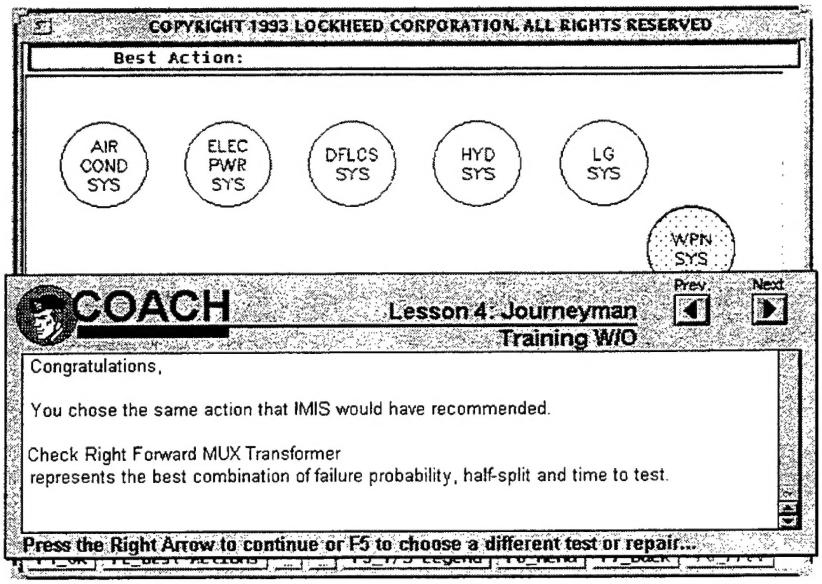

Fig. 132. The Journeyman selects the correct best action.

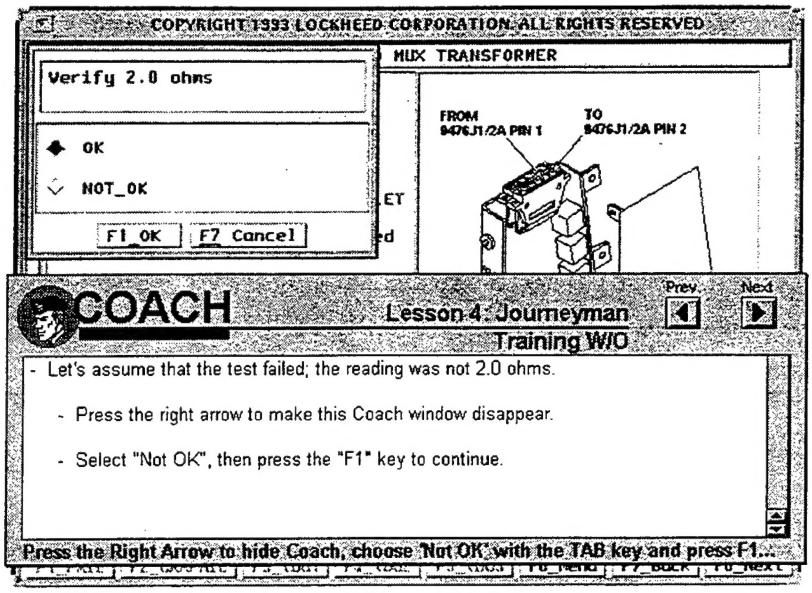

Fig. 133. The testing cycle continues in stand alone mode, with COACH providing the synthesized test results.

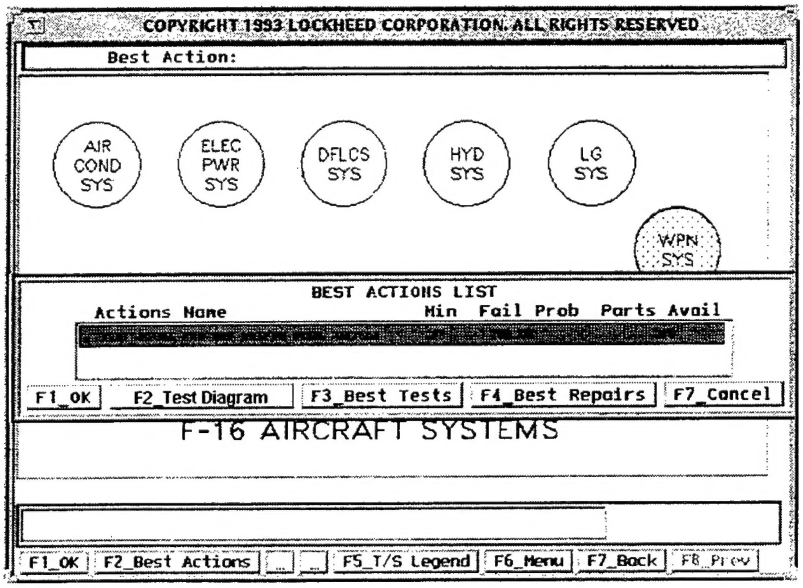

Fig. 134. The final test cycle in this diagnostic scenario begins.

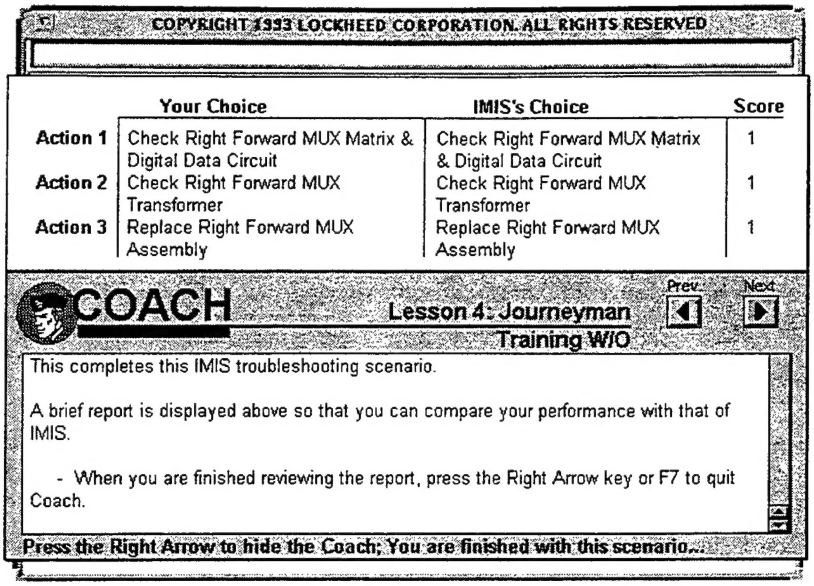

Fig. 135. When the Journeyman completes the diagnostic scenario, COACH provides a simple assessment report.

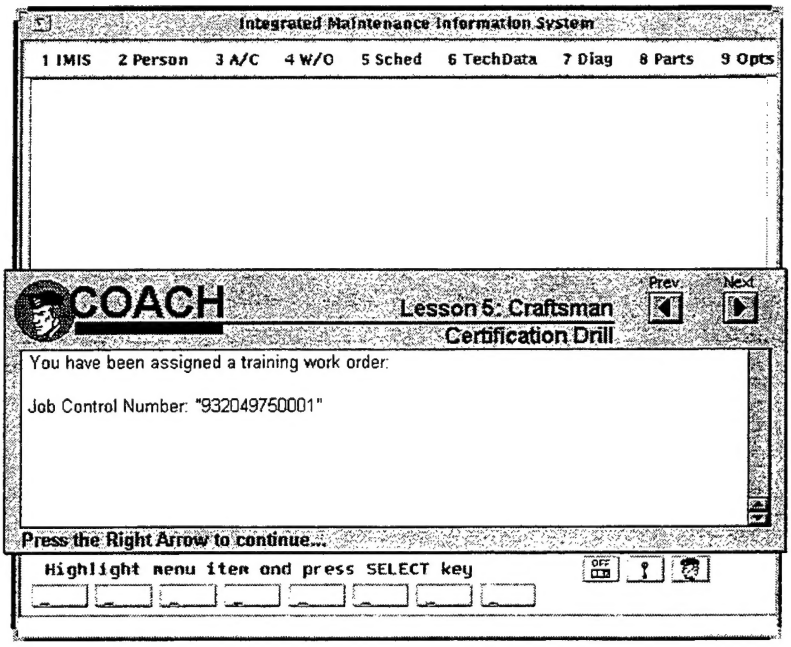

Fig. 136. In the Craftsman level, COACH provides no assistance during the diagnostic scenario is except to provide the test outcomes if it is run in stand alone mode. The Craftsman mode perfect for advanced independent drill and practice or for recertification.

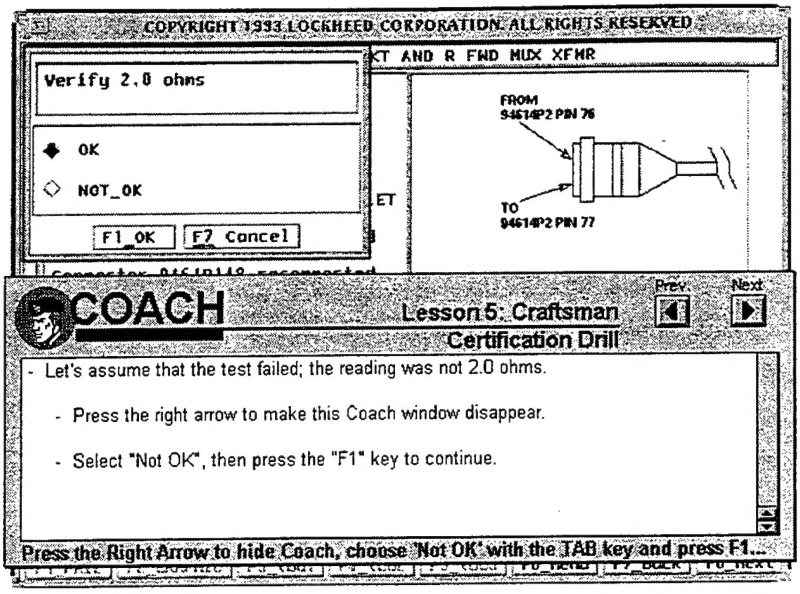

Fig. 137. The Craftsman level assessment report.